

Mr Nixon's Non-Cultural Revolution

By all accounts, and from the appearances of recent weeks, President Nixon's visit to Peking last year has had a profound effect on his management of the United States Administration. Mao Tse Tung's cultural revolution seems in retrospect to have been founded on the belief that nation states should, from time to time, abolish the bureaucracy with which they are endowed and let another regroup in what may appear to be a more natural way. There is an element of this draconian policy in the way in which President Nixon has, for all practical purposes, abolished the machinery for the administration of science and technology in Washington. The Office of Science and Technology is to disappear, and its functions will be shared by the head of the National Science Foundation and by officials of the Office of Management and Budget. But at the same time, the President has gone a long way to dismantle the apparatus by means of which traineeships and fellowships have been provided by the federal government not merely for the encouragement of higher education and scientific research but for their sustenance. But however much the president may have been impressed with what has recently been happening in China, the analogy between China and the United States is not especially apt. The most conspicuous difference between Mao Tse Tung's sweeping away of the old bureaucracy and Mr Nixon's efforts in the past few days is that the former was a radical assault on the establishment but that the latter is a carefully controlled dismantling of what exists. Under Mr Nixon's proposals, there will be few opportunities for the forces which can contribute to the continuing evolution of American society to regroup themselves in advantageous ways—they will have to live within the confines of an extremely straitened budget and within an administrative framework which the White House appears determined to control. Given that much of what the present president has been doing and has announced in his new budget (see page 303) is hostile to intellectual causes, it is fair to say that he has launched not a cultural revolution but the opposite.

What matters about the dismantling of the Office of Science and Technology is not the decision itself but the way it has been done and the motives which have so far been inadequately disclosed. For basic science, the overriding question is which part of the federal government's machinery will be empowered to urge that there should be a continuing federal commitment for basic research, especially at the universities. In the 1950s, Dr James Killian, Science Adviser to Presidents Truman and Eisenhower, persuaded the federal government that it alone could shoulder the obligation to see that basic science flourished and, with the help of people such as Dr Vannevar Bush and agencies such as the Office of Naval Research, the National Science Foundation came into being. With the election of President Kennedy

and the appointment of Dr Jerome Wiesner as Science Adviser, the Office of Science and Technology became an institution in its own right, concerned with technical studies of all kinds but in particular with presenting the case for basic science at a more influential level in the bureaucracy than the National Science Foundation (in the last resort an appendage of the Department of Health, Education and Welfare) could manage. As things have turned out, there is a case for thinking that the Office of Science and Technology is indeed unnecessary—operating agencies ought, in a good Administration, to be free to argue their own cases and should in any case be sufficiently well provided with technical people to understand the technical implications of what they do. The trouble is that the abolition of the Office of Science and Technology is not now accompanied by a declaration from the federal government that the interests of basic science will be safeguarded by the National Science Foundation, nor by an affirmation from the White House that graduate education must be a federal responsibility, but instead by a continuing ambiguous exhortation to the National Science Foundation that its work must be in some sense relevant.

The assault in the new budget on the federal government's provision of traineeships and fellowships will be especially harmful. For the best part of a decade, the National Institutes of Health have by these means powerfully encouraged the development of university research in all branches of medical science but especially in cancer research, to which the Administration still attaches great importance and on which it plans to spend substantial funds. The truth is, however, that it would not be feasible now for the President to say in his budget that the attack on cancer will be prosecuted vigorously in the years ahead if it had not been for the way in which the NIH have spent money on traineeships and fellowships in the past decade. Here, if only the Administration had had the wit to understand, would have been a splendid object lesson in the value of basic research. And although, with the passage of time, it may be possible for universities to find other means of supporting graduate students, there is no doubt that in the immediate future the attenuation of the programmes of the NIH and the NSF in graduate education will harm not merely the potential students but the universities at which they might have followed graduate courses.

How should basic science in the United States respond to the changes now in prospect? One tendency that the universities must be prepared to meet has close parallels with what has recently been happening in Britain. The pressure on funds for research is already so great that universities are being forced somehow to discover a more rational pattern for the sharing of their work. Luckily, there are ways in which, in principle at least, this may be done without undermining the fabric



of the university system—the University Grants Committee and the Science Research Council between them have the instruments of selectivity and concentration in their hands. It will be best for everybody if American universities somehow devise for themselves machinery for regulating their development at a time of contraction, not growth.

Along with this it is important that the academic community should seize every opportunity to ask searching questions about the federal government's now truncated policies for research and development. Is it sensible that the National Science Foundation should be so wedded to applied research when it has yet to demonstrate that it can function as an entrepreneur of innovation more effectively than the other operating agencies of the federal government? Is it proper that so much of the spending of the National Aeronautics and Space Administration should be committed to space flights when what is spent on basic science is being reduced? In the months ahead, it is essential that academics should come out from the covers and urge these and other arguments on the federal government. If in the process they find it necessary to take Senator Edward Kennedy to task for the inconsistencies in his Science and Technology Bill, no harm will have been done.

Another Pretty Flame

A HIGH-RANKING newsman from the BBC confessed on late night television last year that the BBC's television news had lost its head over the eruption of Mount Etna. Too much time, he felt, had been devoted to films of fiery lava, not because it ranked high in social, economic or political importance, but because it was so photogenic.

Now that the Helgafell Volcano in the Westman Islands off the coast of Iceland is claiming chunks of the six, nine and ten o'clock news shows, what is really at fault with television's coverage of such events is plain for all who care about science to see. There is no attempt at all to explain why Iceland should be visited by this form of natural catastrophe so often. When there is a pseudo-science story, such as a man walking on the moon, the television makers trot out their science correspondents, import geologists and physicists and have a field day making papier mache models and diagrams. But none of this treatment is, in fact, given to a genuine scientific news event. No one would know, watching the shooting fires and floating pumice on colour television, that new understanding of the forces at work on the mid-Atlantic ridge and other plates of the earth's crust has been one of the major scientific advances in recent years.

Television is feeding the public the primitive idea that nature is random and capricious. It is doing this particularly in children's programmes. The BBC's vaunted after-school programme, "Blue Peter", has been conspicuously lazy in its approach to science. It devoted a whole segment of a show recently to the Icelandic eruption with no mention of the mid-Atlantic ridge. To fill out its time, the programme dug out old film to show that the Blue Peter team had looked lava in

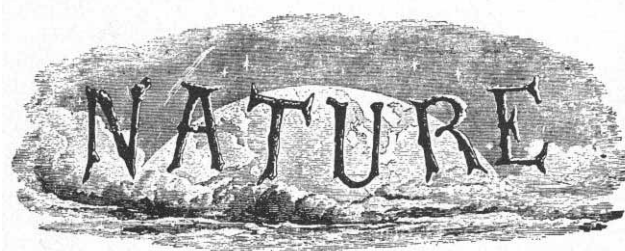
the face at Mount Etna too. The same programme, some days earlier, had discussed tropical fish from the point of view of their ability to harm man. Some fish stung, some bit and others (sharks) could chew people all to bits. The fact that these natural defences were of some advantage to the fish was not discussed.

There has been a voguish anti-rationalism in many television documentaries ostensibly devoted to science and technology which is worrying. For example, the recent programme on the common fear of travel by air seemed to give legitimacy to the fear, on the grounds that many people suffer from it. (Its title was "The Only Way to Go".)

Professor Velikovsky also came in for some less-than-objective treatment from television recently. There was Velikovsky and his theories, on the one hand, and conventional astronomers and their theories on the other, and glowing sunsets suggesting worlds in collision to bind the two together. The science programme, "Horizon", has followed a doomsday line lately.

It is being said that Dr Bronowski's new series, "The Ascent of Man", will correct the anti-science swing inside the BBC. That would be good, but there still needs to be some new thinking on science news itself. There are reasons why the earth's crust bursts open where it does and why earthquakes occur in some places and not others. News editors who just show the pictures without explanation are doing as much disservice to the public as if they showed photographs of bombs and victims without mentioning that there was a war going on.

100 Years Ago



SEDGWICK

GEOLOGY has lost her veteran leader! While yet firm in intellect, full of kind and generous feeling, and occupied on the last pages of the latest record of his labours, in the ninth decade of a noble life, Sedgwick has gone to his rest. Under the shadow of this great loss we look back through more than half a century, and behold no more conspicuous figure in the front ranks of advancing geology than the strenuous master workman, the eloquent teacher, the chivalrous advocate of science, who has now finished his task. Severe illness, borne with fortitude, had gradually withdrawn him from scenes once brightened by his ever-welcome presence, but could not tame the high spirit, or cloud the genial sympathies which had won for him, more than for other men, the loving admiration of his fellows in age and followers in study. Rarely has a patriarchal life been crowned with such enduring and affectionate respect.

From Nature, 7, 257, February 6, 1873.

OLD WORLD

Makings of a French Science Policy

FUTURE French science policy is outlined in the pages of *La Recherche* this week where the leaders of the chief political parties outline their views on science in France in preparation for the general election in March. If election promises are kept, the outlook for science is none too bright.

M. Jean Charbonnel, minister for industrial and scientific development, seems fairly happy with the *status quo*. The organization of French science is more than adequate he says, and the existing problems are simply administrative ones. Medium and small companies must be encouraged to undertake research, even though the 1973 budget has produced a cut in the sixth five-year plan (see *Nature*, **240**, 64; 1972). By the end of the plan (1977) he hopes that the growth rate in science will be back on course, and he points out eagerly that the *grands programmes* of space, computing and nuclear power have been kept viable in spite of budget cuts.

Discussing European problems, M. Charbonnel reaffirms France's desire to see a European space policy, pointing out that if the proposal for the L3S launcher (put to the European Space Conference on December 20) goes through, the project will be centred around French industry and technology, demonstrating the quality of French skills.

Nonetheless M. Charbonnel singles out research on the quality of life as the most important area for study.

The views of the left-wing alliance—a union of the communist and socialist parties—are represented only by the opinions of Roland Leroy, secretary of the central committee of the French Communist Party, as M. Francois Mitterand, the national secretary of the Socialist Party withdrew his replies to *La Recherche's* questions at the last moment. This withdrawal will only feed the fears of those who believe that French politicians are largely uninterested in science policy, and the fact that the leftist alliance may well gain seats in the forthcoming election presents, to many scientists in France, a worrying prospect if Mitterand's actions reflect his interest.

Leroy maintains that, given power, he would completely reverse French science policy, at the same time increasing expenditure on science to 3 per cent of the gross national product. Numbers of French scientists should be increased and most should work in the public

research organizations, while greater efforts should be made for European cooperation. Leroy would also put an end to work on France's atomic bomb, directing the work of the Commissariat à l'Energie Atomique, which he would expand, to more peaceful ends. Leroy, too, would encourage work designed to improve social, working and living conditions.

Michel Poniatowski, secretary general of the Federation of Independent Republicans, and as such a member of the majority, agrees that politicians tend not to be interested in science and blames this on the failure of scientists and civil servants to involve the public in science. He is heavily critical of the way the science plan is developed over a five-month period each year without any knowledge of the final budget within which it will have to operate.

Poniatowski also argues that fundamental science is already well financed, but urges that applied science should receive more attention, particularly in the universities.

The French space programme receives some caustic criticism, M. Poniatowski warning that France must not go ahead alone with a policy that is beyond the limits of its resources. On the other hand oceanography should receive more

attention. Poniatowski would also work to see research scientists and their views included in government deliberations.

Michel Rocard, national secretary of the United Socialist Party, argues that since M. Pompidou came to power there has been no research policy, and he is highly critical of the way American nuclear power companies have been allowed to overtake French expertise. The money poured into the CEA for twenty-five years, he says, has been to no purpose.

The liveliest selection of views offered by the political leaders are those of Jean-Jacques Servan-Schreiber, although his chances of putting them into effect are slim. Science for him is a sacred cow. There is a "plethora of research scientists", he complains; the numbers working for CNRS should be cut, their expertise being distributed among the universities, technical colleges and industry. Only the best qualified research scientists should work in public organizations, and as much as one-fifth of the science budget should be poured into private industry. Much more research should be run on the American contract basis, he says, and the bureaucracy involved in running science at present should be heavily cut down.

SELECT COMMITTEE

Reactor Safety Queried

THE Select Committee on Science and Technology is becoming increasingly concerned about the safety of nuclear reactors, particularly in the light of rumours that the government is to buy light water reactors from the USA.

The committee's concern is underlined by the decision to have a special showing in the next few days of last week's *World in Action* programme on the United States nuclear industry which brought allegations that the light water reactors are not as safe as they might be to the fore again.

This week, however, the committee was assured of the safety of the British steam generating heavy water reactor (SGHWR) by Mr S. A. Ghalib, managing director of The Nuclear Power Group (TNGP), when the group gave evidence to the committee. The select committee has long favoured the SGHWR and is eager to see it built for the Central Electricity Generating Board, and TNGP made it clear that it is equally enthusiastic. Mr Ghalib said

that there is no doubt that the SGHWR is safer than either the pressurised water reactors or the boiling water reactors. Operating experience of the 1 MW prototype at Winfrith and the fact that SGHWR is built on already proven technologies combine, he said, to make development risks minimal.

The group welcomed the proposed merger of the two existing consortia, urging that the new company be made up of three components—themselves, British Nuclear Design and Construction and British Nuclear Fuels. The sooner the reorganization takes place the better according to Sir Edwin McAlpine, TNGP's chairman. Sir Edwin also made it clear that once the reorganization is complete, plans can begin for the formation of an all-European nuclear company, probably the result of an amalgamation of the new British company and Kraftwerk Union of Western Germany. This company, Sir Edwin said, would, in time, probably be the only all-European company operating in Europe, although competition could be expected from Westinghouse and GEC subsidiaries.

POST APOLLO

ESRO Joins in

THE ESRO council last week decided to authorise the establishment of a "special project" to develop a sortie laboratory that will fly with the NASA space shuttle in the 1980s.

The estimated cost of the sortie laboratory is between \$250 million and \$300 million and so far Germany, Italy, Belgium and Spain have agreed to participate. It is expected that other countries will signify their intentions to join now that the decision to participate has been taken.

ESRO is at present instituting a series of studies on the design of the sortie laboratory which are expected to be completed by the end of 1973. The organization intends to carry on the special project through the final design stage to the development stage and it is provisionally planned to deliver a flight unit to NASA in 1979.

The sortie laboratory will consist of two parts one of which will be a pressurized capsule that will accommodate up to six people and the other an unpressurized unit that will be suitable for conducting experiments for up to 30 days in space. The laboratory will be carried into orbit by a shuttle orbiter and will remain attached to the shuttle during its entire time in space. At the end of each mission the orbiter will land at the launch site and the laboratory will then be removed and prepared for the next mission.

As yet Britain has not decided whether to join her ESRO partners in this scheme. A spokesman for the Department of Trade and Industry said this week that the possibilities were being actively considered but that no decision should be expected in the near future.

ESRO's decision to join the post Apollo programme comes more than eighteen months after the original offer was made.

WATER RESOURCES

A Watered-down Bill

TEN regional water authorities and a National Water Council are to be set up under the government's Water Bill published last week (HMSO, £0.63).

The bill will bring a long overdue rationalization to the 29 river authorities, 160 water undertakings and 1,300 sewerage authorities that currently make up the water services in England and Wales.

There were few major changes in the bill's clauses from the proposals first circulated by the Department of the Environment in December 1971, but the local authorities, which had resented losing their control of sewerage

functions and water supply to the new RWAs, are thrown a sop in that they will have a majority of the seats on each authority. As a result the consumers' councils that were part of the original proposals and were intended to represent the views of the local authorities and other interests, have been dropped.

The National Water Council remains all that the Water Resources Board and its allies have feared it would be. The council is to be purely advisory, without a strong staff of its own.

Pressure on parliamentary time has resulted in the British Waterways Board, which is responsible for canals in Britain, receiving a reprieve, but one which may well be withdrawn later. Legislation to tighten up pollution control has also been dropped for the same reason, although the government promises to make amends when it introduces its wide ranging environmental bill which will also cover noise, air and waste pollution.

As a gesture towards conservation the Natural Environment Research Council is to be made responsible for informing the regional water authorities of any sites of special interest within their jurisdiction which may not be nature reserves but which may be affected by the authorities' activities.

UNIVERSITIES

Better than Evens

A MARKED increase in the number of students applying for university places to read medicine and a drastic decline in the numbers of students wanting to read mathematics, physics, chemistry and some engineering subjects are reported in the tenth report of the Universities Central Council on Admissions published last week.

Table 1 Comparison of Number of Candidates Applying for University Places in 1971 and 1972

Subject	Number of applicants		Number admitted *
	1971	1972	
Medicine	8,971	11,177	2,955
Mathematics	6,041	5,451	3,687
Physics	3,017	2,807	2,280
Chemistry	3,405	2,857	2,466
Engineering and Technology (total)	17,644	16,859	9,035

*Admitted through UCCA only. Some Scottish universities do not participate fully in the UCCA scheme.

The increase in the prospective medical students from 8,971 in 1971 to 11,177 in 1972 is the more striking because the total number of British applicants for places in all departments fell from 114,968 to 113,966. But the total number of applicants increased

POLLUTION

Cleaner Air

ALTHOUGH Lancashire, Cheshire and the High Peak District of Derbyshire are among the most polluted areas in Britain, the average concentrations of smoke and sulphur dioxide in the atmosphere have decreased by 55 per cent and 40 per cent respectively during the past decade (*National Survey of Air Pollution, 1961-71*, HMSO, £3.50).

The average concentration of smoke and sulphur dioxide in the north-west during the 1968-69 and 1969-70 winters was 143 and 178 micrograms per cubic metre respectively, in urban areas. In the industrial part of South Wales, however, only three sites out of twenty-six had smoke levels greater than 50 micrograms per cubic metre and only two sites showed the sulphur dioxide level to be greater than 100 micrograms per cubic metre. But in the south-western part of Britain, Wiltshire, Gloucestershire, Dorset, Somerset, Devon, Cornwall and the Scilly Isles the comparable levels of smoke and sulphur dioxide were 13 and 39 micrograms per cubic metre respectively.

The surprisingly low figures for South Wales are due to the low volatile matter and low sulphur content of the coal mined in this area.

slightly because the number of overseas candidates for places increased from 9,016 in 1971 to 10,393 last year. Of this total, the eighty-one institutions which participate in the UCCA scheme admitted 60,510 students.

Although there were almost two applicants for every university place last October 2,744 places were left unfilled. Of these vacancies, 1,400 were in engineering and technology, and more than 600 in the sciences, but there were also more than 840 vacancies left in the Arts. On the positive side, medicine, dentistry and health departments accepted 224 more students than they had planned to take, so that 5,397 students started courses in these subjects.

UCCA handled 21,585 students in its clearing scheme once A-level results were known, and the council managed to find places for more than 6,500 of these. But 8,682 students were not referred to a university either because their A-level grades were not good enough or for some other reasons.

Even though on the face of it it seems that there were almost two applicants for every university place, UCCA stresses that the situation is in fact better, for between 15 and 20 per cent of the applicants did not have the minimum examination qualifications required by any university and 13 per cent of the applicants were applying for the second or even third or fourth times.

NEW WORLD

Belt Tightening in Store for US Science

by our Washington Correspondent

ANOTHER period of financial starvation is in store for science and technology in the United States. That is the prospect held out by President Nixon's austere budget for the 1974 financial year (which starts on July 1 this year), which was sent to Congress earlier this week. The budget proposed an overall increase in expenditure on research and development which is clearly insufficient to keep pace with inflation and, moreover, it is also made clear that cutbacks in some areas—notably space and some biomedical research—will not wait until next year, but will be put into effect immediately.

The overall strategy for science and technology outlined in the budget is to allow increases in areas of research likely to benefit society—energy, transportation, cancer, disease of the heart, lungs and blood vessels, and drug abuse are all set for relatively large increases in research money. But this largesse will be offset by cutbacks elsewhere. And, in spite of the fact that the United States is at last moving towards a peacetime economy, defence-related research and development is again set for a large increase. Basic research comes off particularly badly in the budget.

The reason for such a gloomy outlook for science and technology is that after proposing expansionary budgets to Congress for the past two years, President Nixon has decided to slam the brakes on public expenditure in order to make good his promise not to increase taxation. In effect, he has partially abandoned the teachings of John Maynard Keynes and returned to the era of balanced budgets.

As a first step, he will slash more than \$11,000 million from federal expenditures this fiscal year—which is already more than half way through—to keep total government spending below \$250,000 million. And the budget which he has proposed for 1974 sets an upper limit of \$268,700 million, which is an increase of about 7.5 per cent, most of which will be swallowed up by inflation and by commitments made in previous years. Sharp reductions are planned for many programmes, but social services, agricultural subsidies, unemployment assistance and President Johnson's great society programme figure prominently among the casualties. In relation to these programmes, science and technology fare relatively well.

The total budget for research and development is due to increase from \$16,500 million last year, to \$17,100 million this year, and to reach \$17,430 million next year. Not all of this money will be spent immediately, however, since obligations often extend over several years, and the actual spending

pattern presents a rather more alarming picture. Total expenditures on research and development last year came to \$16,103 million, this year they will drop to \$15,886 million, and pick up again next year to \$16,790 million (see Table 1). The effects of this dislocation in spending will be most severely felt

White House Unveils the Plan

by our Washington Correspondent

PRESIDENT NIXON has finally announced his intention to dismantle the science policy apparatus that was set up in the White House by Presidents Eisenhower and Kennedy during the panic that followed the launching of Sputnik. As expected (see *Nature*, 241, 234; 1973), the Office of Science and Technology is to be abolished and the National Science Foundation will become the focal point in the federal government for the formulation of US science policy.

The post of Science Adviser to the President, which was vacated by Dr Edward E. David earlier this year, will also be scrapped and Dr H. Guyford Stever, director of the National Science Foundation, will assume the role of chief science adviser to the White House. He will advise the President through Dr George Shultz, Secretary of the Treasury and the President's Assistant for Economic Affairs. The changes were formally announced in an executive reorganization plan which was sent to Congress at the end of last week.

Congress has 60 days in which to comment on the plan and if it is not blocked it will be put into effect on July 1 this year. Although the plan does not mention the President's Science Advisory Committee, it is understood that it will be abolished along with the Office of Science and Technology. Dr Stever, in theory, will be called upon to advise on policies involving all types of science and technology, but it is expected that advice on military research and development will usually come from the Department of Defense and the National Security Council will also take on some additional responsibilities in this area. Similarly, the director of the National Institutes of

Health will probably continue to be the chief source of advice to the White House on biomedical research.

The reorganization plan also involves scrapping the National Aeronautics and Space Council—the White House Committee with the vice-president as chairman which has the task of coordinating policies for space and aeronautics. The NASC was originally formed in response to the launching of Sputnik, and its duties have largely been carried out by the National Aeronautics and Space Administration during the past few years.

Although the reorganization plan has at last been published, several questions still remain about the new structure. For one thing, Dr Stever will be faced with at least a potential conflict of interest in being director of a federal agency, and at the same time offering advice to the Office of Management and Budget about how the science budget should be divided. At the same time, the National Science Foundation will not be getting any new staff or an increase in budget to help it carry out its new functions. Dr Stever said last week that the Foundation's budget for 1974 will allow it to increase its staff by about 20 people, but the extra staff is needed for existing NSF programmes such as RANN (Research Applied to National Needs). If new staff members are taken on specifically for the new science policy functions, presumably it will be at the expense of other NSF activities.

Asked last week when he was first brought in on discussions of the plan, Dr Stever replied, "About two weeks ago". The plan was therefore drawn up in the White House and presented to the National Science Foundation more or less as a *fait accompli*.

Table 1 Conduct of Research and Development (in millions of dollars)

	Obligations			Expenditures		
	1972 actual	1973 estimate	1974 estimate	1972 actual	1973 estimate	1974 estimate
Defense—Military functions	8,294	8,338	8,808	8,117	7,873	8,333
National Aeronautics and Space Administration	3,183	3,383	2,995	3,373	3,008	3,066
Health, Education and Welfare	1,763	1,832	1,969	1,513	1,670	1,873
Atomic Energy Commission	1,298	1,359	1,411	1,298	1,359	1,411
National Science Foundation	456	461	516	418	423	446
Transportation	351	367	425	274	290	359
Agriculture	353	378	351	349	360	343
Interior	220	259	262	210	262	255
Commerce	184	214	211	165	179	187
Environmental Protection Agency	122	177	138	133	146	164
Veterans Administration	71	76	78	66	71	75
Housing and Urban Development	47	43	71	47	43	61
Justice	24	39	54	13	30	46
All other	134	184	141	127	173	171
Total, conduct of research and development	16,500	17,110	17,430	16,103	15,886	16,790
Total, conduct of research	6,483	6,689	6,737	6,169	6,300	6,555
Total, conduct of development	10,017	10,421	10,693	9,934	9,586	10,235

in the Department of Defense, NASA and NIH.

Obligations for science and technology will at least increase both this year and next, but at rates of 3.7 and 1.9 per cent respectively, they will obviously be insufficient to keep pace with inflation, which is running at between 4 and 5 per cent. Moreover, if those figures are contrasted with the promises made a year ago in the 1973 budget, a better idea of the extent of the freeze in science and technology can be gained. The 1973 budget proposed increases in obligations for research and development from \$16,500 million in 1972 to \$17,800 million this year. Similarly, expenditures were set to increase from \$15,800 million to \$16,480 million. The estimate for obligations this year is thus \$700 million less than the estimate made a year ago, and the proposed budget authority for next year will be \$400 million less than the total originally proposed for this year.

The \$600 million difference between the original and the revised estimates for expenditures on science and technology in the 1973 fiscal year gives some indication of the effect on research and development of the \$11,000 million cut-back in total federal expenditure which President Nixon has ordered—more details of the cutbacks will be sent to Congress later this week. It represents a reduction in the science budget of nearly 4 per cent which, although it will result in some severe dislocations, is rather less than expected.

Expenditures on science and technology unfortunately fall in the category of relatively controllable federal outlays—only about \$87 million could be cut from federal expenditure this year, the remainder of the budget being made up of commitments carried over from previous years, or of expenditures such as pensions and veterans' benefits which cannot be reduced. The \$11,000 million total cut in federal expenditure thus amounts to about 13 per cent of the

controllable funds, and the 4 per cent cut in the science budget is therefore relatively mild. At least one official of the Office of Science and Technology has suggested that the OST can be given some of the credit for preserving the science budget from the full weight of the axe. Whether the new arrangements announced last week (see box) would be equally effective is a moot point.

The outlook for academic science has also been soured by financial stringencies this year and the promise of belt tightening next year. Expenditures by the federal government in science departments of colleges and universities are expected to increase by 4.7 per cent this year, and by 4.9 per cent between this year and next (see table 2). Such increases are barely sufficient to keep pace with general inflation, and clearly too small to account for the so-called sophistication factor. Moreover, they are considerably below the estimates made a year ago—the 1973 budget estimated about a 10 per cent growth in expenditures on academic science between 1972 and 1973, with the 1973 figure climbing to \$1,964 million.

Although total obligations for science and technology are set to increase by only \$320 million between the present financial year and 1974, defence research alone is scheduled for an increase of \$370 million. Moreover, re-

search and development related to the production of energy is due to be increased by \$130 million, research into cancer and heart disease is set for a \$92 million increase, and research related to transportation, reducing loss of lives and property from natural disasters, and curbing crime and drug trafficking is scheduled for an increase of \$115 million. Clearly, therefore, other fields are being cut back to accommodate the increases.

The following are among the more prominent casualties:

- Training grants and fellowships at the National Institutes of Health are being abolished and nearly every research institute apart from the politically sensitive National Cancer Institute and National Heart and Lung Institute will suffer an absolute cut in operating expenses next year. Moreover, the Administration is now proposing to slash nearly \$87 million from its original budget request for the present fiscal year for all Institutes except for Cancer and Heart and Lung (see page 306).

- Budget cuts in the National Aeronautics and Space Administration, which were announced earlier this month (see *Nature*, **241**, 83; 1973), will result in the cancellation of the High Energy Astronomy Observatory programme, development of nuclear propulsion, and work on communications satellites. The space shuttle and some aeronautical research will also suffer small budget cuts (see page 306).

- Agricultural research is being re-organized, and cut drastically both this year and next. The total budget authority for the agricultural research service will decline from \$228.5 in 1972 to \$205.0 this year and \$185.8 in 1974. The chief move will be to concentrate agricultural research in fewer facilities and to drop projects considered to be of low priority. The implications for universities and colleges are not yet clear.

- The Administration is continuing its policy of reducing direct support of graduate students by finally abolishing the National Science Foundation's

Table 2 Research and Development in Colleges and Universities (in millions of dollars)

	Obligations			Expenditures		
	1972 actual	1973 estimate	1974 estimate	1972 actual	1973 estimate	1974 estimate
Health, Education and Welfare	874	885	935	721	765	839
National Science Foundation	374	378	423	342	347	365
Defense—Military functions	212	219	218	219	225	219
National Aeronautics and Space Administration	119	117	114	131	123	119
Atomic Energy Commission	85	84	87	85	84	87
Agriculture	88	96	77	79	88	73
All other	116	128	143	94	118	134
Total	1,868	1,907	1,997	1,671	1,750	1,836

traineeship programme and decreasing its graduate fellowship programme. The foundation's basic research support programmes are, however, set for a modest increase.

● A death warrant has been written for yet another high energy accelerator—the Cambridge electron accelerator—and the operating budgets of every accelerator except the 200 BeV machine are being cut. The total operating budget for high energy physics is set to increase by \$4.1 million between 1973 and 1974. But the National Accelerator Laboratory is scheduled for an increase of \$9.8 million—it will be the first full year of operation of the 200 BeV machine—the Cambridge electron accelerator will only get \$600,000 and will be phased out, and the budgets of the Alternating Gradient Synchrotron, the Zero Gradient Synchrotron, the Bevatron, the Stanford linear accelerator and general research and development will be reduced by the following amounts: AGS—\$400,000, ZGS—\$1.2 million, Bevatron—\$1.8 million, SLAC—\$750,000, and general research and development—\$150,000.

President Nixon's budget now goes to Congress, where it has to go through the annual authorizations and appropriations ritual. Although there will be no shortage of battles over many of its provisions, it is unlikely that Congress will be either willing or able to influence the total amount proposed for science and technology, for two chief reasons. First, the expenditure cuts proposed for the present fiscal year result chiefly from the fact that the Office of Management and Budget has impounded funds already approved by Congress. Unless such action is judged unconstitutional—its constitutionality is being challenged in the courts in at least two specific cases (see *Nature*, **240**, 436; 1972)—Congress at present has no recourse. And second, President Nixon has served notice in no uncertain terms that he will stick to the expenditure limit of \$268.7 million which he has proposed for next year. Congress thus seems to have two options: either it can devise some mechanism by which the appropriations committees can reorder the priorities in the budget, but stay below the ceiling prescribed by President Nixon, or it can increase appropriations as it sees fit, only to have them vetoed by Nixon or the extra funds impounded by the Office of Management and Budget.

Past experience suggests that Congress will probably take the second course, and continue to do battle with President Nixon over his power to impound funds—a variety of bills seeking to limit such power have already

been introduced. But in either case, it is unlikely that the general trends in the portion of the budget allocated to science and technology will be altered. US science is thus clearly heading for yet another period of financial stringency.

NATIONAL SCIENCE FOUNDATION

Caught in the Squeeze

by our Washington Correspondent

THE budget for 1974 gives the National Science Foundation modest increases in its funds for the support of basic research and a larger helping for its applied research activities. But the overall increases proposed for the foundation are insufficient to keep pace with general inflation and clearly too small to take account of the so-called sophistication factor which drives up the cost of scientific research.

Nevertheless, the foundation has probably come out of the budgetary process with as much cash as can be expected in the light of the squeeze on all items in the federal budget. Its budget will increase from \$597.7 million in 1972 to \$610 million this year and to \$636.5 million in 1974 (see Table 1). The Office of Management and Budget has impounded \$62.4 million of the foundation's funds for the present fiscal year, as part of President Nixon's plan to hold overall federal expenditure down to \$250,000 million, the chief cuts being made in the foundation's education and graduate student support programmes. That accounts for the fact that the foundation will have about 10 per cent less money available this year than Congress appropriated.

As far as basic research support is concerned, the budget asks for \$275 million next year, up from \$261 million this year and \$248.6 million in 1972. Within this total, all branches of science are scheduled for modest increases and none has been cut back. Nevertheless, the total being requested for 1974 is

exactly the same as the original request for 1973, and so in effect the increases requested a year ago are being spread out over two years.

The foundation's applied research activities fare a little better, however. Requests for the programme of Research Applied to National Needs (RANN) total \$79.2 million in 1974, compared with estimated expenditures of \$70.0 million this year and \$53.8 million a year ago. The Experimental Technology Incentives Program is also set for an increase, from \$15 million this year to \$18 million next—this is a new programme launched this year in conjunction with the National Bureau of Standards. The NBS's share of the venture is due to be increased from \$7 million in 1973 to \$8 million in 1974.

The graduate support provided by the National Science Foundation is again scheduled for a decrease, from \$14 million this year to \$9.2 million next, a cut which reflects the fact that the NSF graduate traineeship programme is being abandoned at the end of 1973. As for education improvement, this is set for an increase of some \$13 million, to \$60 million next year. The chief reason for the exceptionally low figure for 1973 is that the Office of Management and Budget withheld \$30.8 million of the funds appropriated by Congress for this purpose.

During the past few years, a ritual has been established in which the authorizations committees in Congress increase the foundation's budget for education and graduate support, and the Office of Management and Budget withholds the increases. Since the committees earmark the money for those specific programmes, none can be transferred to other NSF activities and the foundation winds up with less money than it would if the committees had left it alone. Whether the same farce will be repeated this year remains to be seen, but the foundation's budget clearly has no room at all for further cuts.

Table 1 NSF Budget (in thousands of dollars)

	1972 actual	1973 est.	1974 est.
1. Scientific research project support	248,574	261,001	275,000
2. National and special research programmes	85,886	114,740	99,600
3. National research centres	39,735	39,538	48,000
4. Computing activities	12,544	10,000	10,000
5. Science information activities	9,711	8,300	8,300
6. International cooperative scientific activities	4,245	4,700	6,200
7. Research applied to national needs	53,767	70,000	79,200
8. Intergovernmental science programme	1,078	1,000	1,000
9. Institutional improvement for science	20,961	9,000	9,000
10. Graduate student support	20,340	14,000	9,200
11. Science education improvement	73,388	47,000	60,000
12. Planning and policy studies	2,929	2,000	2,000
13. Programme development and management	24,562	28,722	29,000
Total direct programme	597,720	610,001	636,500

NIH

The Bubble Bursts

by our Washington Correspondent

THE crusades against cancer and diseases of the heart, lungs and blood vessels have finally taken their toll on other areas of biomedical research. The budget presented to Congress this week calls for large increases in the budgets of the National Cancer Institute and the National Heart and Lung Institute, but proposes sharp cutbacks in funding for all other institutes in the Institutes of Health. Moreover, the Administration has proposed that NIH training grants should be phased out and that federal support for the training of doctors should be sharply curtailed.

These proposals are likely to be fiercely resisted by Congress, which has consistently backed large increases in funding for biomedical research during the past few years, but there seems little prospect that Congress will be able to prevent at least those decreases which are due to be brought into effect immediately.

institutes of NIH is given in Table 1. The figures represent obligations not all of which will necessarily be spent in the year to which they are assigned. The situation is somewhat complicated by the fact that the appropriations bills for the Department of Health, Education and Welfare have not been passed into law because President Nixon twice vetoed HEW appropriations because he considered them to be inflationary. The totals given for 1973 therefore represent revised Administration proposals.

A large part of the cutback in 1974 funds results from the Administration's decision to phase out NIH training grants. The rationale behind this decision is that the grants were necessary to increase biomedical manpower at a time when budgets for biomedical research were increasing, but now that such budgets have been stabilized, demand for manpower will slacken off. The Administration also believes that scientists studying for PhDs will eventually earn enough money to pay back any loans they may need to finance their studies.

ties of the squeeze were announced earlier this month (see *Nature*, **241**, 83; 1973), and funding for them has already been withheld from the agency's budget for 1973. As for the 1974 budget, which was unveiled last week, NASA is being allowed new starts on only two relatively small satellites, and its total outlays will decline from \$3,423 million last year to \$3,062 million this year and increase to \$3,136 million in 1974.

As far as the Office of Space Science is concerned, the chief casualty is the High Energy Astronomy Observatory programme, which has been suspended for a review to see whether its objectives can be accomplished more cheaply. Dr Naugle, director of OSS, said last week that NASA is looking at the possibility of flying some of the HEAO experiments on an Atlas-Centaur rocket, and he hopes to have some definite plans to present to Congress during the budget hearings. The agency has, however, managed to preserve the Viking mission to make a soft landing on Mars in 1975, the two Mariner flyby missions to Jupiter and Saturn to be launched in 1977 and to keep the Explorer programme at about the same level as this year.

Funding for sounding rocket research is being held constant, at \$20 million, and the only increase in NASA's physics and astronomy programme is in payload definition for the shuttle, which is budgeted at \$500,000 in 1974, up from \$308,000 this year. As for the planetary programmes, no approved missions have been scrapped, but there is no money in the budget for the Venus-Pioneer programme. In the middle of the negotiations between NASA officials and officials of the Office of Management and Budget, the Venus-Pioneer programme was revamped to save a total of about \$50 million in the runout costs (see *Nature*, **240**, 177; 1972). But it seems that the play was unsuccessful. Asked last week whether the absence of money for the mission meant that it had been scrapped, Dr Fletcher said that NASA is still engaged in defining the programme, and hopes to get some money for it in the 1975 budget. The launch window for the first planned mission is 1977, however, which means that if it is approved, funds will have to build up rapidly.

As far as other parts of the NASA budget are concerned, the shuttle has taken a small cut, which will delay the first orbital flight by about nine months—from early 1978 to the end of that year. Skylab and the Apollo-Soyuz test project have emerged unscathed from the budget process. With Nixon's budgetary intentions now evident, NASA must be relieved that ESRO has finally decided to join the post-Apollo programme, and build the sortie laboratory.

Table 1 Obligations for the National Institutes of Health (thousands of dollars)

Institute	1972	1973	1974
National Cancer Institute	372,838	426,093	500,000
National Heart and Lung Institute	224,389	247,075	265,000
National Institute of Dental Research	42,366	40,333	38,452
National Institute of Arthritis and Metabolic Diseases	145,032	139,806	133,608
National Institute of Neurological Diseases and Stroke	111,557	105,539	101,198
National Institute of Allergy and Infectious Diseases	103,986	100,726	98,693
National Institute of General Medical Sciences	166,358	151,587	138,573
National Institute of Child Health and Human Development	112,515	109,551	106,697
National Eye Institute	35,555	33,797	32,092
National Institute of Environmental Health Sciences	25,889	25,889	25,263
Research Resources	130,211	99,019	88,632
Fogarty Center	4,357	3,926	3,586
Total	1,457,053	1,483,341	1,531,776

President Nixon's budget proposes that the budget of the National Cancer Institute should be increased to \$500 million in 1974, and that of the National Heart and Lung Institute should climb to \$275 million. Such sums would increase the budgets of the two institutes by \$74 million and \$18 million respectively, from the levels proposed for 1973. To offset these increases, President Nixon has recommended that about \$73 million should be cut from the budget requests of all the other research institutes in the present fiscal year and that these new budget levels should be reduced by a further \$43 million next year. The \$73 million reduction in the budget authority of these institutes in the present fiscal year results from the cut of \$11,000 million in overall federal expenditure ordered by President Nixon.

The overall picture for the research

So far, budgets for cancer research and for research into diseases of the heart, lungs and blood vessels have been exempted from the general budget freeze. Whether they will continue to be exempted when it becomes clear that a cure for cancer will not be found in the next few years remains to be seen.

NASA

Space Constraints

from our Washington Correspondent

FOR the second year in succession, the National Aeronautics and Space Administration has had to take a large cut in its budget and to curtail activities which, according to NASA administrator James C. Fletcher, were "important to the nation's space and aeronautics program". Most of the casual-

NEWS AND VIEWS

Record Solar Activity in August 1972

DURING early August 1972, sunspot activity was responsible for a remarkable series of effects, which were observable on the solar surface, in interplanetary space and at the Earth. Three communications in this issue of *Nature* (pages 331, 333 and 335) are concerned with these events. Two are devoted to cosmic-ray studies and the third marks the advent of a new branch of solar spectroscopy at ultra-high energies.

Intense solar activity is usually associated with complex sunspot groups which in turn represent regions of enhanced solar magnetic field strength, typically several thousand gauss. Within the sunspot group a solar flare may occur; this is characterized by bursts of X-rays, optical line emission and radio waves at frequencies of the order of hundreds of MHz. Strong solar flares may emit white light for a short period and may also accelerate charged electrons and nuclei to relativistic energies, in the case of protons up to several times 10^9 eV. The nature of the acceleration process of these solar "cosmic" rays is not understood. Perhaps they are pre-accelerated in some large-scale magnetic trap by interaction with magnetic waves and only released during the flare. Alternatively the flare may reflect particle acceleration in a region where oppositely directed magnetic field lines annihilate each other and an intense electric field is set up.

More detailed angular and wavelength resolution in observations of solar activity is required to help sort out this problem, and the communication by Chupp and his colleagues (page 333) provides suitable new information on the fast protons, previously only observable when they reached the Earth or a space vehicle. Direct knowledge of the accelerated electrons comes from the radio measurements but, in the case of the protons, interaction with matter must be detected. Chupp *et al.* used a large scintillator crystal on an OSO satellite and on August 4 and 7, 1972, recorded spectral emission lines at low energy gamma-ray energies during two flares. Although preliminary measurements in this energy range date as far back as 1958 (Winckler and Peterson, *Nature*, **181**, 1317), this was the first occasion on which line emission has been detected. The lines originate from the interaction of fast protons moving downwards with matter in the atmosphere of the solar photosphere. Secondary positrons are probably responsible for a spectral line seen at 0.51 MeV, and deuterons, arising from secondary neutrons, are likely to have caused the 2.22 MeV line found by Chupp *et al.*

A companion article, by Mathews and Lanzerotti (page 335), is related to the previous work. These authors have studied the arrival at the Earth of the accelerated solar "cosmic" rays from the flare on August 7, as measured by some standard monitoring devices. By careful timing they have shown that the energetic protons must have been accelerated at the time of peak flux in the white light emission, rather than at the later time of the peak of radio and optical line emission. Thus it

is thought that the white light is caused by heating of the photospheric atmosphere a few hundred kilometres above the solar surface by the downward-moving energetic protons which appeared in the acceleration process (see Svestka, *Solar Phys.*, **13**, 471; 1970).

A fast stream of plasma is ejected into interplanetary space in association with the flare activity, and it is such a stream which caused the cosmic-ray storm discussed by Pomerantz and Duggal (page 331). Interplanetary space is always filled by the expanding plasma layers of the outer solar corona and this plasma motion, at about 400 km s^{-1} , is known as the solar wind. Magnetic field is carried out from the Sun by the highly conducting plasma and is responsible for screening off some relativistic cosmic-ray nuclei from the Galaxy. The charged cosmic rays diffuse inwards, colliding with magnetic scattering centres moving outwards and losing energy as they go. The effect of the fast plasma stream linked with the flare is, however, not simply to enhance the screening process. Observations such as those of Pomerantz and Duggal show that cosmic-ray storms are made up of a series of sharp (Forbush) superimposed decreases in the cosmic-ray intensity at the Earth, often followed by a rapid recovery. Changes of intensity at the rate of 5 per cent an hour were seen in one event. And changes of particle flux are often highly dependent on direction of view. Thus it is logical to look for some large-scale barrier in space as the basis of a way to explain cosmic-ray storms.

The fast stream late on August 4, caused perhaps by a flare on August 2, reached a plasma velocity of $1,100 \text{ km s}^{-1}$, about the highest ever recorded by a Pioneer spacecraft. Preceding the stream was a shock front in which the magnetic field strength jumped from 30 to 40 gamma to 50 to 80 gamma ($1 \text{ gamma} = 10^{-5} \text{ gauss}$) according to preliminary HEOS-2 satellite data. (At quiet times the strength of the interplanetary field is no more than 6 gamma.) The shock was still very noticeable at the Pioneer on its way to Jupiter, 3.5 AU from the Sun. At the time these plasma changes were taking place the cosmic-ray intensity near the Earth is deduced to have fallen to half of its value before the storm. Only one other comparable event has been recorded, in July 1959. A theoretical explanation of the sharp cosmic-ray decreases can probably be sought either in the barrier associated with the shock jump in interplanetary field strength or, perhaps more likely, in a far-reaching plasma/field discontinuity known as a tangential discontinuity, which is expected to exist within all such interactions between the fast streams and solar wind. Magnetic field lines do not cross a tangential discontinuity, so charged particles should find it an effective barrier. Further joint analysis of satellite, space probe and cosmic-ray data for these events of August 1972 should enable a better picture of the properties of fast plasma streams ejected under flare conditions to be built up.—J. J. Q.

Crumbs from the Rich Man's Table

At least so far as molecular biology is concerned the New Year has got off to a bright start. Much sweat has flowed under the bridge since transfer RNA was first crystallized. The incandescence of the early optimism gradually gave place to plaintive tales of unstable crystals, nonisomorphous replacements, twinning, and all the other calamities that crystallographers are heir to. Yet here suddenly come Kim and his eight colleagues from Rich's laboratory at the Massachusetts Institute of Technology, tripping down the primrose path to atomic resolution.

Success was evidently contingent, as so often in the early days of protein crystallography, on the witchcraft of good isomorphous replacement. In an article in the December issue of the *Proceedings of the National Academy of Sciences* (69, 3746; 1972) Kim *et al.* refer to the preparation of three heavy-atom derivatives, one containing three platinum atoms, the second two samarium and the third an osmium. It was the last that proved crucial; it involved first the preparation of a nucleotide osmic ester, from ATP and a bipyridine osmate complex. When this was diffused into the tRNA crystal it reacted stoichiometrically at a single site, the 3' terminus, where sugar *cis* hydroxyl groups are available for complex formation. In this article a resolution of 5.5 Å was described—barely sufficient to reveal the outlines of the molecule, which was surmised only to be elongated with here and there some constrictions. The molecules are set well apart in the lattice, and in between are solvent-permeated channels. Here and there what seemed to be the phosphodiester chain could be made out, and a loop appeared to run round the outside of a part of the molecule.

Only another two months sufficed to give these shadows substance in a 4 Å model (Kim *et al.*, *Science*, 179, 285; 1973). Here concentrations of electron density corresponding to the individual nucleotides can be discerned. The molecule resolves itself into a rough L-shape. The course of the backbone is for the most part easily traced by moving from one maximum to another the right distance away. Where the assignment is equivocal, it can be resolved by reference to the base-pairing scheme imposed by the cloverleaf model. Complete consistency between the cloverleaf scheme and the conformation in the crystal is in fact indicated, though the tertiary structure is far from cruciform. The authors are collecting data at 3 Å, which will allow them to define the structure uniquely without regard to external evidence.

It already seems, however, that there can be little doubt about the correctness of the model. The most striking feature is that there are only two lengths of double helix, each of about one turn. This means that the base-paired stems are collinear in pairs. The duplex formed by the two terminal segments of the chain is continuous with the stem of the pseudouridine loop, and is connected in the middle by way of two single-stranded segments (one of them the "extra loop") to the second double helix, made up of the base-paired stems of the dihydrouracil and the anticodon loops, the two helices lying more or less at right angles to one another. The variable length of the "extra loop", which has anything from four to twenty-one residues in

the tRNA species of known sequence, can be readily accommodated, because it lies on the outside, linking the two arms of the L at their centres. Four residues in fact is the minimum length that will span the distance. The acceptor end, the 2' hydroxyl CpCpA, projects outwards at an angle, and may be free to take up different orientations at will.

The implications of the model will have to be digested at leisure, but the authors have already noted that it accounts readily enough for various features of the chemistry, such as photodimer formation between the thiouracil residue at position 8 and cytosine at position 13. Three-dimensional models based on inferences from chemical and physical properties have, of course, dropped into the literature and vanished as rain upon the desert's dusty face; none, one may confidently predict, will survive this model. Only the base-pairing—Holley's original cloverleaf—seems unassailable. Moreover, a comparison of the X-ray data with earlier and more rudimentary results from the same laboratory on another species, formylmethionine tRNA, indicates that the gross structures must be very similar. This encourages the hope that all tRNAs will fit into the same mould structurally, just as their base-pairing schemes conform to the cloverleaf. The 3 Å model, which should yield, among other bonuses, the long-awaited proof that the base-pairing is of the Watson-Crick type (or not as the case may be), as well as a wealth of miscellaneous structural information, to illuminate accumulated experimental data, will be eagerly awaited.—From our Molecular Biology Correspondent.

Human Papova Viruses

To the numerous laboratories throughout the world that are preoccupied with cancer research the recent discovery of latent human papova viruses must come like manna. With a minimum of effort such laboratories can now submit research proposals and grant applications that surely stand a good chance of being accepted and funded. All they have to do is to propose to repeat, using human papova virus(es), the elegant and important experiments that have been carried out with simian virus 40 during the past several years. One thing seems incontestable; this new human virus is the human counterpart of SV40, a latent monkey virus that induces tumours in rodents if not in monkeys and transforms rodent cells growing in culture.

The human papova virus (whether there is just one species or several related species is not yet known) first came to light in 1971 when Gardner and her colleagues detected it in the urine of a person who had undergone kidney transplant surgery and was being treated with immunosuppressives. Subsequently the same virus or a very closely related virus was detected by Weiner and his colleagues in biopsies of brain tissue from patients with progressive multifocal leucoencephalopathy and

Weiner's group have since begun to investigate the virus by propagating it in cultured cells.

Now on page 343 of this issue of *Nature* a South African group, Lecatsas *et al.* working in Pretoria, report detecting a papova virus in the urines of no less than eight patients who had received kidney transplants. The concentration of virus in the urine and the duration of its presence apparently varied considerably from patient to patient and there was no obvious correlation between the date of detection of the virus and the date of the kidney transplantation. There may, however, be a correlation between the appearance of the virus and the use of antilymphocytic serum as an immunosuppressive. Apparently, all eight of the South Africans excreting the virus were given horse antilymphocytic serum, whereas, when working in London in 1971, Lecatsas failed to detect the virus in 150 urine samples from 31 kidney transplant patients who were not receiving antilymphocytic serum but were receiving immunosuppressive drugs. These various findings indicate, of course, that the multiplication of this latent human virus seems to depend on the immune status of an individual.

Obviously it must now be discovered whether this human papova virus(es), like SV40, has an oncogenic potential and can, for example, induce tumours in rodents and transform rodent cells in culture. From what is known about SV40 it would not be at all surprising if the human virus has an oncogenic potential. Whether, however, it is ever involved in the induction of cancer in its natural host, man, is another question. Lecatsas *et al.* propose to follow up the patients which they know have excreted the virus to see if they develop tumours and if they do whether or not the papova virus can be detected in the tumour cells, and no doubt other groups will use serological tests to see if there is any correlation between appearance of the virus and the development of tumours. But if what is known about SV40 is anything to go by nobody will be surprised if these tests all prove negative, and this human papova virus joins the ranks of other viruses which are not apparently involved in carcinogenesis in their natural hosts even though they are oncogenic in other species.—From a Correspondent.

ORGANOCHLORINE PESTICIDES

DDT Levels in Barracuda

GROSSLY misleading information can result from spot checking fish tissues for fat soluble pollutants in order to estimate local environmental pollution, according to the evidence of Deichmann, Cubit, MacDonald and Beasley (*Arch. Toxikol.*, **29**, 287; 1972) who have looked for organochlorine pesticides in the abdominal fat of adult barracuda shark caught in Florida waters. These pesticides enter coastal waters by terrestrial runoff and relatively large quantities of soil-bound DDT and related pesticides settle as the current decreases. As a group they are very insoluble in water, but quite soluble in fats, oils and organic solvents. DDT, as traces in solution, floating in surface films and as bottom sediment is subsequently partially absorbed by aquatic plants and marine organisms and moves through the food chain which forms the chief source of pesticide intake by fish.

Pesticide monitoring programmes have revealed that most of the fish in the waters of the United States contain DDT. They also frequently contain dieldrin, sometimes heptachlor epoxide, chlordane and heptachlor, and occasionally lindane, aldrin or endrin. Most analyses show that the "total" DDT (DDT plus its metabolites) contained in fish is less than the United States Food and Drugs Administration tolerance level of 5.0 p.p.m. for the edible portions. Concentrations of pesticide in individual tissues vary considerably; the highest concentrations

are generally found in body fat. Deichmann *et al.* analysed 281 giant barracuda (*Sphyrna barracuda*); 63 per cent were found to have more than 5 g abdominal fat, and of these "fat" fish, 96 per cent contained DDT or one of its isomers or metabolites. Except for the smallest and the largest fish, the ratio of the milligram "total" DDT in fat to kilogram body weight remained constant, although the p.p.m. increased with increasing size.

Little abdominal fat was found in the barracuda with fully or nearly fully developed gonads, at the height or near the end of the spawning season (June to September). The concentration of "total" DDT was calculated in other organs and, unexpectedly, only traces were found in the ripe gonads; the fish had lost approximately 75 per cent of their "total" DDT, the female fish carrying the smaller load. Starving was not the cause of this loss of body fat plus pesticides during spawning because the stomach contents of these fish were even slightly greater than at other times. Other workers have reported high levels of pesticides in prespawning gonads, and high mortality of larvae in lake trout has been attributed to metabolism of yolk fats containing DDT. Deichmann *et al.* do not know what happens to the pesticides during the spawning season, except that they are returned to the water, to a cycle of uptake and excretion.

Two important facts emerge from this work. First, a high level of DDT in fish does not necessarily mean that greater than FDA levels will be ingested as the fat and oil containing the pesticide separate from the fish during heat-

Localization of Human X-Linked Genes

DURING the past several years cell geneticists have exploited the parasexual event of fusion of somatic cells in culture to identify linkage groups; for example, by fusing mouse and human cells and correlating the loss of human chromosomes with the loss of human enzymes from the hybrid cells it has proved possible to identify which chromosomes carry the genes for at least a few human enzymes. Obviously such experiments do not localize genetic markers to particular regions of any chromosome but, by exploiting recognizable translocations, a more precise localization of markers to particular regions of chromosomes is possible, as Ruddle and Ricciuti report in *Nature New Biology* next Wednesday (February 7).

Ruddle and Ricciuti have studied a translocation between the human X chromosome and the human D-14 chromosome detected in a mother and her mentally retarded son. Fibroblasts

from these two persons were placed in culture, fused with cells of a mouse line, RAG, lacking hypoxanthine guanine phosphoribosyl transferase (HGPRT) and grown in HAT medium which selects for the retention of the human HGPRT gene which is X-linked, as are the genes for glucose-6-phosphate dehydrogenase (G6PD) and phosphoglycerate kinase (PGK).

Analyses of the pattern of segregation of these human genetic markers and the segregation of the X chromosome translocation led Ruddle and Ricciuti to the following conclusions. First, all these three markers are apparently located on the long arm of the X chromosome. Second, it seems probable that "G6PD and HGPRT are more closely linked to each other than either are to PGK". These experiments also prove that with patience and ingenuity somatic cell geneticists can assign markers not just to chromosomes but to particular regions of those chromosomes.

ing. An entirely different situation arises in the preparation of high protein animal feed, however, as then the whole fish is used. Second, the analysis of body fat of barracuda and similar non-migratory "fat accumulators" is a useful method of estimating local pollution, provided that year-round analyses are carried out because spot checking would lead to erroneous results.

INSECT VISION

Superposition

from our Insect Physiology Correspondent
It is now more than eighty years since Exner published his classic monograph on the optics of the compound eyes of insects and crustaceans. Exner's views have long been accepted virtually unchallenged; only in the past few years have his results been subjected to renewed critical tests, notably by G. A. Horridge and his colleagues. The classic theory of mosaic vision by the compound eye is commonly attributed to Johannes Müller, early in the nineteenth century; but it had, in fact, been put forward by Robert Hooke a century and a half earlier. According to this theory the retinal image is formed by the apposition of partial images produced by each facet of the compound eye. These partial images convey to each retinal element, or rhabdom, a stimulus characterized by their average intensity of illumination, and the resulting definition in the "apposition image" depends on the number of facets in the surface of the eye.

The most original contribution by Exner was the theory that in the eyes of nocturnal insects and some Crustacea, in the dark adapted state, the screening pigment around the optical pathway from the crystalline cone to the receptor rhabdom is withdrawn between the crystalline cones, leaving a clear zone below; and that the refractive properties of the lens cylinder, or crystalline cone, are such that light rays are deflected back towards the side from which they enter the facet, in such a way that they converge in the clear zone, and a single retinal element receives light not only from its own facet, but also light from the same point source entering through a group of neighbouring facets. The resulting image was named by Exner a superposition image. It was demonstrated most convincingly in isolated portions of the eye of the glow-worm *Lampyrus*. Exner noted that the erect image so formed did not fall precisely at the level of the retina—but he suggested that this might be due to his using isolated and cleaned preparations from the eye.

Horridge first examined the eye of the firefly *Photuris* and found that no

superposition image could be demonstrated. He termed the eyes with a wide gap between the crystalline cones and the receptor rhabdoms of the retina clear zone eyes (as opposed to superposition eyes, which implies a particular mode of operation.) In the meal-moth *Ephestia* there are glassy threads extending from the lens of each ommatidium to the rhabdom. These threads act as light guides which conduct most of the light received by each facet to its own rhabdom and thus a normal apposition image is produced. Furthermore, there is some scattering of light at the inner extremity of the lens and some of this reaches the retina by an indirect route. There is also a certain amount of refraction of the type described by Exner in the superposition eye—but it is too indefinite to form a useful superposition image. The eye in the dark adapted state enjoys greater general illumination but any contribution to image production must be highly diffuse.

In their most recent report, however, Horridge, Giddings and Strange (*Proc. Roy. Soc. Lond.*, **B182**, 457; 1972) show that in the skipper butterflies (Hesperiidae), which are day-flying insects, there is a wide clear zone which is never interrupted by screening pigments; the pigment remains permanently between the crystalline cones even in the brightest illumination. There are glassy threads from the cones to the rhabdoms, but these are so fine that they cannot serve as wave guides for light. In the eye of these skipper butterflies the superposition principle is fully operative under all conditions of lighting and gives rise to an erect image that is

tolerably sharp and is formed at the level of the receptors. Ingenious new methods were devised by which the image can actually be seen inside the eye. It would seem that although the

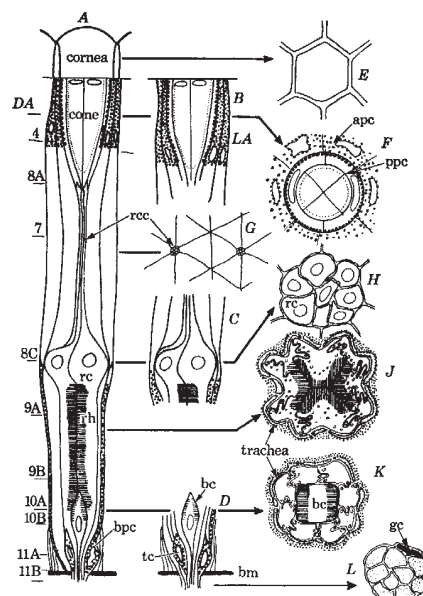


Diagram of an ommatidium, as found by electron microscopy in the skipper butterflies (figure from Horridge *et al.*, *Proc. Roy. Soc.*, **B182**, 460; 1972). *apc*, Accessory pigment cell; *bc*, basal retinula cell; *bm*, basement membrane; *bpc*, basal pigment cell; *gc*, glial cell; *ppc*, principal pigment cell; *rc*, retinula cell body; *rcc*, retinula cell column; *rh*, rhabdom; *tc*, tracheal cell.

superposition principle does not operate in all clear zone eyes, in some insects it really does exist in a highly efficient state.

TYMV RNA as an Amino-acid Donor

THE single stranded genomic RNA of turnip yellow mosaic virus (TYMV) has some striking similarities to transfer RNAs. The structure of the 3' end of this viral RNA apparently resembles the structure of a tRNA and the last three bases of the viral RNA are CpCpA. The ultimate A residue is metabolically labile and can be added by tRNA nucleotidyltransferase and the viral RNA can be charged with valine by valyl-tRNA synthetase. These findings prompted Haenni *et al.* to determine whether or not charged TYMV RNA can donate its valine residue to nascent polypeptide, and as they report in *Nature New Biology* next Wednesday (February 7) the viral RNA can mimic tRNA in protein synthesis.

In a protein synthesizing cell free system programmed with poly (G,U,C) valyl TYMV RNA donates its valine to polypeptide at about one-fiftieth the efficiency of valyl-tRNA. Further-

more, this reaction is blocked by puromycin and experiments with inhibitors of aminoacyl-tRNA synthetases prove that valyl TYMV RNA donates its valine directly.

In a companion report Prochiantz and Haenni describe a series of experiments which indicate that TYMV RNA is a substrate for the *Escherichia coli* endonuclease which converts tyrosine precursor tRNA to mature tRNA. This finding suggests that when valyl TYMV RNA donates its valine residue during protein synthesis the 3' terminal portion of the TYMV RNA, which resembles tRNA, is cleaved from the rest of the viral RNA molecule.

From these results it seems plausible to speculate that the evolution of the TYMV genome has involved either the convergent evolution of a tRNA-like sequence or the attachment of a tRNA to the rest of the viral RNA molecule, an intriguing situation.

ADENOVIRUSES

Ad2 and SV40

from our Cell Biology Correspondent

WHAT renders a cell non-permissive and unable to support the replication of any particular virus is one of the more interesting questions which virologists face and no doubt the molecular basis of non-permissiveness will prove to be manifold, with different mechanisms operating against different viruses in different cells.

One of the few pertinent cell-virus combinations that has been investigated in some detail is the infection of African green monkey kidney (AGMK) cells by human adenovirus type 2 (Ad2). This virus cannot replicate efficiently in AGMK cells even though the virion penetrates the cells, is uncoated and its DNA is transcribed and replicated. When, however, Ad2 and simian virus 40 coinfect AGMK cells the yield of progeny Ad2 is increased by about 1,000-fold. Precisely how SV40 acts as a helper for the replication of Ad2 in these cells and renders them permissive remains unknown, but recent experiments carried out by Lucas and Ginsberg (*J. Virology*, **10**, 1109; 1972) seem to eliminate all but two possibilities; namely either SV40 protects some Ad2 mRNAs from partial degradation by endonucleases or SV40 specifies some function which allows late Ad2 messengers to be translated.

Lucas and Ginsberg have used DNA-RNA hybridization techniques to compare the extent of transcription of the Ad2 genome in AGMK cells, in AGMK cells coinfecting with SV40 and in permissive human KB cells in which the adenovirus replicates without the aid of SV40. They also used immunological precipitation techniques to compare the amounts of adenovirus structural proteins made in these various infections. The hybridization experiments, which were carefully conducted to eliminate artefacts, reveal that both early and late species of Ad2 messengers are synthesized in KB cells and AGMK cells in the absence of SV40. Furthermore, the non-conservative maturation of these messengers and their transport to the cytoplasm are comparable in both sorts of cells. In AGMK cells, however, in the absence of SV40 the synthesis of adenovirus structural proteins is some 90-fold less than the synthesis achieved in the presence of SV40 helper. Apparently therefore AGMK cells support transcription of Ad2 DNA, but the viral RNA is not translated.

Lucas and Ginsberg do not yet know whether or not the late Ad2 messengers are partially degraded and not available for translation. If it proves that these RNAs are degraded, and they are addressing themselves to this question,

SV40 must somehow protect the molecules from the endonuclease(s). If, on the other hand, the late Ad2 messengers in AGMK cells are as stable as they are in KB cells Lucas and Ginsberg will look for a function specified by SV40 that directly promotes the translation of Ad2 messengers. The result, whatever it is, will be interesting.

In the same issue of the journal (*ibid.*, 1126) Bhadani, Raskas and Green report a method for partially purifying milligram amounts of Ad2 messenger RNA from KB cells some 18 hours after infection. They have simply exploited the fact that at high ionic strengths the polyadenylic acid tails of the messengers cause them to bind to cellulose nitrate filters. As they point out, these mRNAs should prove useful for analysing the synthesis of adenovirus proteins in cell-free systems and, of course, if Lucas and Ginsberg find that the SV40 helper function is directly involved in facilitating translation, such cell-free systems may provide a means of identifying precisely the helper function.

DATING TECHNIQUES

Using Carbon-14

from a Correspondent

THE intention of the eighth international conference on radiocarbon dating, which was organized by the Royal Society of New Zealand at Lower Hutt on October 18-25, was to bring together scientists engaged in operating dating laboratories and in evaluating results. The programme was designed to deal with technical aspects of dating and the significance of isotopic ratios measured in the

estimation of radiocarbon dates and with the environmental factors that might affect the interpretation of the results in terms of absolute years. It was not intended to provide a forum for the discussion of actual projects using carbon-14 dates primarily as indicators of time supporting other geochemical or archaeological evidence. The chief emphasis was on the problems of the variation of concentration and residence times of carbon-14 in ocean water; the role of radiocarbon in freshwater and in soil development; the effects and amounts of various contaminants on dates; and on considerations of suitable standards for carbon-14 activity.

It was appropriate that the meeting was held at Lower Hutt—nine miles from Wellington—because this is the site of the New Zealand Department of Scientific and Industrial Research whose director, Dr A. Rafter, with the collaboration of Dr G. J. Fergusson, established the first carbon-14 dating laboratory, with a range surpassing 55,000 years, in the Southern Hemisphere.

Of general interest were the contributions on secular variations of atmospheric radiocarbon. There are three distinct areas. Dr W. Fergusson (University of Arizona) reported that the bristlecone pine chronology had been extended by another 1,000 years to nearly 8,200 BP and that he would shortly have wood of this age available for radiocarbon analysis. Dr E. Ralph (University of Pennsylvania) and Professor P. Damon (University of Arizona) described separate methods for dealing with the nearly 400 determinations in the literature of the radiocarbon ages of dendrochronologically

Inducing Polyoma Virus Production

IN *Nature New Biology* next Wednesday (February 7) Fogel describes further experiments with the line of rat embryo muscle cells transformed by the large plaque strain of polyoma virus which he and Sachs established in 1967. This line of transformed cells is of interest because at a frequency of about 1 in 10^4 the cells are spontaneously induced to release polyoma virus. Furthermore, various physical and chemical agents which cause DNA breakage increase the frequency of induction of virus synthesis.

In his latest experiments Fogel allowed the cells to incorporate varying amounts of 5-bromodeoxyuridine and then exposed them to various doses of visible light, a procedure which results in single strand breaks in the cell DNA. He reports that after such treatment the number of cells containing polyoma

virus capsid antigen can be increased by some 600-fold and the number of cells producing virus can be increased by about 100-fold. The number of infectious virus particles produced per cell, however, decreases.

One obvious explanation of these data is that the extensive DNA breakage induced by the treatment is lethal to the cells which do not survive long enough to produce much virus. This idea is supported by the observation that exposure of the cells to cysteamine at the time of irradiation increases cell survival up to 70-fold, decreases some 2-3-fold the number of cells containing capsid antigen but increases the number of virus particles produced per cell. All these data indicate that the replication of polyoma virus in these cells is induced by single strand breakage of the cellular DNA.

dated wood, in order to provide a calibration of the radiocarbon time scale that could be used for converting conventional radiocarbon dates to calendaric dates.

It was disappointing that the conversion graphs and tables produced by the two methods did not agree sufficiently well for the conference to advise their adoption for calibration purposes. This adoption must be deferred until at least the next international conference on dating, for new data will make little difference to the curves for some time. The causes of carbon-14 variations in terms of geomagnetic and heliomagnetic cycles as well as climatic changes at the end of the last glaciation were sought as explanations by Professor A. Fairhall (University of Washington), Dr E. Ralph (University of Pennsylvania) and Dr M. Baxter (University of Glasgow). Dr Baxter warned that fluctuations induced by Sun spots could introduce uncertainties of up to 120 years in the dating of short lived materials such as grain, straw, seeds, single tree rings, twigs or egg shells.

Professor G. Östlund (University of Miami) introduced the GEOSECS oceanic programme, the purpose of which is the detailed measurement of the chemical constituents of water along sections from the Arctic to Antarctic in the Pacific and Atlantic oceans from surface to bottom. These measurements will provide a set of physical and chemical data that can be used for quantitative studies of ocean mixing and ocean productivity. They will also provide a base line for levels of pollutants and of fission and waste products being added to the sea. One of the most important sections of the programme is the measurement of carbon-14, because its half life is comparable with the time scale of mixing processes occurring in the deep ocean. Special carbon-14 laboratories are being established at Miami and Seattle (Professor M. Stuiver) to deal with the anticipated 1,200 samples each of 200 litres of water.

The nuclear bombs exploded since 1955 have doubled the radioactive carbon dioxide in the troposphere, and large doses have been injected into the lower atmosphere through the tropopause gap. All terrestrial tissues have reacted naturally to this and compounds involved in the usual processes of photosynthesis and feeding have had a fraction of all their carbon positions labelled. Mr H. S. Jansen (Institute of Nuclear Sciences, Lower Hutt) pointed out that there was now an opportunity for measuring residence times (that is, the mean time before a carbon atom residing in a tissue is replaced by atmospheric carbon) in such a way that could be expected to

reflect biochemical processes in the animal or plant tissue without conducting experiments which might alter the process. He regretted the fact that the opportunity was being lost by the workers in the life sciences because the activity was at present falling by 1.5 per cent each year. He assumed that this lack of use of "bomb carbon" is probably attributable to inadequate communications between disciplines.

In an attempt to redress this, Mr Jansen has compiled families of curves for various latitudes and different years of origin or birth of the tissue. He has plotted $\Delta^{14}\text{C}$, relative radiocarbon enrichment of the tissue against calendar years so that, at a glance, a researcher can read off the rate of replacement from the curves. Other experiments can be planned with their aid.

Synthesis of Myeloma Light Chain DNA

THE biological role of tumour virus reverse transcriptase is apparently the synthesis of a DNA provirus during the establishment of infection, but be that as it may this enzyme in the hands of biochemists is an invaluable tool for the synthesis of DNA chains which can be labelled to a high specific activity and which are complementary to specific cellular RNA molecules. Single stranded DNA molecules complementary to at least part of globin messenger RNA molecules have recently been synthesized and partially purified, and in next Wednesday's *Nature New Biology* (February 7) Aviv, Packman, Swan, Ross and Leder report the synthesis of a DNA complementary to about 40 per cent of a mouse myeloma light chain messenger RNA.

Aviv *et al.* purified reverse transcriptase from avian myeloblastosis virus and partially purified light chain messenger RNA, which in a cell free system

stimulates immunoglobulin light chain synthesis, from mouse MOPC 41 tumour cells. Using oligo (dT) as a specific primer of reverse transcription, the oligo (dT) presumably hydrogen bonds to the poly (A) residues at the 3' terminus of the mRNA molecules, they synthesized a 5S DNA which contains about 325 nucleotides. Hybridization experiments with this DNA and poly-somal RNAs from MOPC 41 cells and another line of myeloma cells, MOPC 315, indicate that the product of reverse transcription is heterogeneous.

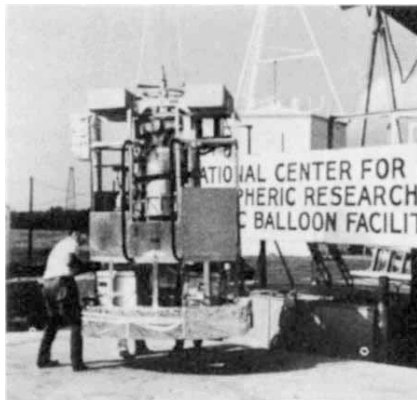
In addition to a major species of DNA complementary to the light chain mRNA DNAs complementary to RNAs common to both MOPC 41 and MOPC 315 cells are made. As Aviv *et al.* point out, however, it should be possible to purify the major DNA species and use it to discover the number of myeloma light chain genes in these mouse MOPC 41 cells.

Two New Infrared Sources Discovered

STUDIES of astronomical sources in the infrared continue to be carried out by the group at University College, London. Telescopes carried on balloon flights from Texas last September scanned known objects, and also resulted in the discovery of two new

sources, not previously detected in the infrared. These objects, RCW 117 and DR 15, are both HII regions, and were previously known by their radio emission.

Details of the observations are reported by Emerson, Jennings and Moorwood in next Monday's *Nature Physical Science* (February 5). RCW 117 appears as a compact infrared source, smaller than the 4 arc min beamwidth of the detector. It seems that it is a compact HII region, whereas the other object discussed in this work, DR 15, is not particularly compact. The new observations at infrared frequencies have made it possible to test the theory that much radiation is produced by the degradation of ultraviolet photons by dust grains. The data suggest that the amount of ultraviolet energy required could be supplied by an underlying young O star within the HII region, but that the radiation would then have to be coupled very efficiently to the dust.



The UCL balloon-borne infrared telescope being rigged at NCAR, Texas, shortly before launch.

EARTH'S CRUST

Velocity Inversions

from our Geomagnetism Correspondent

ALTHOUGH the so-called Conrad discontinuity is no longer recognized as a world-wide crustal boundary, the existence of more localized discontinuities in the Earth's crust is well established. During the past few years, however, evidence has been accumulating for a different, though related, crustal feature—one or more velocity inversions which effectively form low velocity layers analogous to the better-known low velocity asthenosphere in the upper mantle.

The most important of this evidence comes from large secondary P_c refraction signals which arrive about a second later than the weaker P_g refractions at distances from several tens to at least 100 km from the shot point, although additional data are provided by normal-incidence and wide-angle observations of high-frequency intracrustal reflexions. The practical point here is that detailed interpretations of these components are now possible because of instrumental advances which have allowed the generation of broad-band recordings on magnetic tape that can be digitized and processed by digital computer. This has led to a corresponding growth in the use of the record section, comprising a series of seismograms digitally processed and plotted on a reduced time scale to permit the resolution of small velocity variations.

What has emerged from such studies is support for the existence of an upper crustal low velocity zone with a P wave velocity of about 5.5 km s^{-1} and a sharp lower boundary in the range 8–15 km. This zone is apparently not world-wide, although data compatible with it have been obtained from many continents, most frequently in areas which have been subject to major tectonic activity at some time in their geological history. The nature of the layer is not certain; but one suggestion is that it comprises semi-continuous acidic intrusions with lower densities and velocities than the surrounding country rock, and in this connexion it is interesting to note that most of the shallow earthquakes in continental areas have focal depths similar to the depths suggested for the low velocity zone. By contrast, a second low velocity layer, thought to be at depths of about 20 km beneath much of North America and Eurasia, is apparently associated with lower than normal resistivity which may be the consequence of the presence of non-meteoritic water.

As a result of the 1968 Carnegie Institution of Washington seismic experiment in the Peru-Bolivia altiplano, Ocola and Meyer (*Geophys. J.*, **30**, 199;

1972) have been able to add to this picture, first, by confirming the presence of the shallow crustal low velocity layer in that part of South America, and, second, by discovering a second low velocity zone rather deeper than 20 km. By tracing rays in a spherical Earth in such a way as to fit the characteristics of the relevant record sections, Ocola and Meyer have come up with a seismic model which agrees with the average model previously derived by Ocola *et al.* (*Earthquake Notes, Seismol. Soc. Amer.*, **42**, 3; 1971)—an upper sedimentary-metamorphic layer with a thickness of 4–9 km and a velocity of $4.5\text{--}4.9 \text{ km s}^{-1}$, a middle "granitic" layer down to 26–30 km and having a velocity of $6.0\text{--}6.1 \text{ km s}^{-1}$, and a lower "gabbroic" layer extending to 68–70 km with a velocity of $6.8\text{--}6.9 \text{ km s}^{-1}$.

But in order to explain the large amplitudes of the secondary arrivals with apparent velocities close to those of the first arrivals, it is necessary to superimpose two low velocity layers upon this average structure. The first layer—evidence for which comes from the southern Peru record section—is the shallower and thinner of the two, has boundaries at 9 km and 12 km, possesses a velocity of 5.0 km s^{-1} , and is overlain and underlain by material having velocities of 6.0 km s^{-1} and 6.1 km s^{-1} , respectively. The deeper and thicker low velocity zone has boundaries at 30 km and 40 km (Bolivia) or 36 km and 46 km (Peru), has its own velocity of 6.15 km s^{-1} , and has material of 6.8 km s^{-1} above and 6.9 km s^{-1} below. In other words, the upper zone lies within the "granitic"

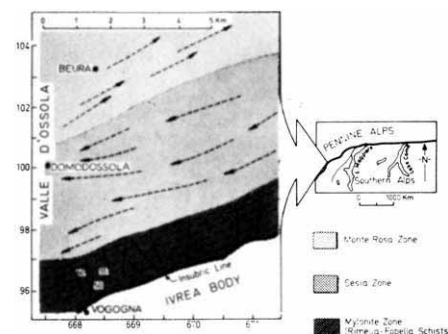
Mylonites on the Insubric Line

THE Insubric Line (sometimes called the Insubric Fault) in the Alps has been described as a late Alpine fault, the site of a Mesozoic collision trench and a post-metamorphic strike-slip fault. In short, its nature and history are subjects of disagreement, though this is perhaps hardly surprising in view of the fact that it lies in one of the most geologically complex areas of the world. Nevertheless, it is clearly a major tectonic boundary, for it forms the southern limit of high-grade Alpine metamorphism and most of the Pennine nappes, it separates radiometric age provinces and it probably forms a boundary between zones of different palaeomagnetic declination.

As a contribution to the debate on the history of the Insubric Line, Johnson reports in next Monday's *Nature Physical Science* (February 5) the results of an investigation of some of the mylonites which form part of the early section of the line outcropping west of Locarno (see diagram). This section has a character quite different from that of the later section to the east which is a clean-cut fault where mylonites, though present, are sporadic and predate the fault. The particular area studied by Johnson is the Valle d'Ossola where the Insubric Line separates the Pennine nappes from the Ivrea Body, a formation which is thought to be a slab of mantle-type material dipping towards the south-east.

Johnson is able to distinguish three episodes of deformation in the Valle d'Ossola mylonite zone—the development of the mylonite fabric from the gneisses of the Sesia Zone to the north; the development of small (amplitudes up to 30 cm) close reclined folds which deformed the mylonitic foliation; and the development of open and close crenulation folds with axial planes

steeply dipping NW. The tectonite fabric of the mylonites apparently evolved during the first two of these episodes. These two episodes saw intense compression across the mylonite zone with the deformation plane lying roughly N-S. The principal axis of compression, however, which after the first deformation was oriented perpendicular to the mylonitic foliation, apparently rotated at the start of the reclined folding, though it returned to its original direction at the end of the second deformation.



But perhaps of greater importance is the orientation of the principal axis of extension. This axis is fairly steeply inclined, rather than sub-horizontal, in the area investigated by Johnson, which seems to imply that in this region the Insubric Line is not a strike-slip fault. This is why Johnson distinguished between the early and later sections of the line, because in the latter case there is definite evidence of strike-slip displacement. As for the meaning of "early" and "later", both in relation to absolute time and to the formation of the Pennine nappes, there is evidence for an early Alpine age for the deformation episodes (though a pre-Alpine age is not ruled out) and Johnson is "tempted" to correlate the deformations directly with the nappe formation.

layer of the average profile and the lower zone lies within the "gabbroic" layer.

As to causes, Ocola and Meyer also point to the question of electric resistivity (or its reciprocal, conductivity). It transpires that as a result of the "exceptional" attenuation of body waves under the Andes in southern Peru and northern Chile, discovered in 1958, various conductivity studies were actually carried out in Bolivia and Peru between 1963 and 1966 in an attempt to discover high temperature material. For example, on the basis of analyses of induced fields from both daytime and night-time magnetic variations, Schmucker *et al.* (*Carnegie Inst. Wash. Yearbook*, 65, 11; 1966) concluded that a "large-scale induced subterranean jet current is guided into a high conductivity channel under the crust of the Andes", and from this and other evidence, suggested that "a highly conductive sub-stratum comes close to the surface". Later, Schmucker (in *The Application of Modern Physics to the Earth and Planetary Interiors*, Wiley, 1969) noted that the depth of this high conductivity zone would have to be less than 50 km. These findings are clearly consistent with previously discovered associations between high conductivity (low resistivity) and velocity inversions.

The low velocity zones are apparently also consistent with various geochemical-petrological conclusions drawn by Pichler and Zeil (1970, quoted by Ocola and Meyer), who suggested that the acidic and basic lavas in northern Chile and southern Bolivia derive from different parent magmas at different depths. Ocola and Meyer point out, for example, that if each low velocity layer has the same composition as its corresponding host rock but is at a higher temperature, it would be "logical" to regard the shallow low velocity zone as the source of the acidic lavas and the deeper zone as the source of the basic lavas. Thus petrochemical studies, as electrical conductivity studies, imply a higher temperature origin for the low velocity zones.

Finally, in a quite different part of the world, Bamford (*Geophys. J.*, 30, 101; 1972) has also used record sections, to obtain the first evidence for a low velocity zone in the crust beneath the British Isles. The basic data in this case were obtained in the 1969 Continental Margin Refraction Experiment between Wales and Ireland; and first arrivals have already been interpreted by Bamford (*Geophys. J.*, 24, 213; 1971) in terms of a single-layer crust. But a new analysis of later refractions and reflexions indicates a 4-5 km thick low velocity layer beginning at less than 12 km and having an average P wave velocity of 5.9 km s⁻¹. Immediately below the low velocity zone the

P wave velocity is 6.4 km s⁻¹, and immediately above it is 6.2-6.3 km s⁻¹. Bamford is concerned to point out, however, that these figures were obtained assuming horizontal layering and are thus only approximate.

PHYSICAL METALLURGY

How to Design an Alloy

from our Materials Science Correspondent
METALLURGISTS have dreamed of sitting down with paper, pencil and slide-rule to design an alloy ever since Henry Sorby first used the microscope to examine the fine structure of metals and alloys more than a century ago. That episode signalled the beginning of the science of physical metallurgy and more generally (for Sorby also pioneered the use of the microscope in geology) of the scientific study of microstructure.

Real life has, however, been singularly resistant to this dream. Part of the difficulty has been that so much of the really interesting detail of microstructure is below the level of resolution of the optical microscope; this objection has been removed now that the electron microscopy of thin metal films is a fully mature technique. The problem now is a theoretical one; microstructures are only statistically determinate: they cannot be described by a set of precise drawings, as can a car or a bridge. Correspondingly, the statistical theories relating, in particular, mechanical properties at different temperatures to microstructure are subtle and necessarily inexact. Overall, the physical metallurgist, as he gains in knowledge and insight, can predict the kind of alloy and the kind of treatment that will approach the desired outcome: the empirical component can never be totally exorcised.

Several case histories to illustrate the gradual improvement in the design/empiricism ratio have been assembled and analysed by Cahn (*J. Metals*, February 1973). In particular, he analyses the stages by which the Nimonic and other high-temperature alloys for jet engines came to be improved: these stages involved, alternately, advances in theory and purely experimental leaps forward. Almost simultaneously with this survey, an account has appeared of the invention (there is no other word for it) of a high temperature alloy. Berghezan and Fourdeux (*Metallography*, 5, 485; 1972) entitled their article "The Design of Specific Microstructures in Order to Obtain Materials with Desired Properties"—an ambitious but justified title.

Briefly, what these Belgian investigators have done is to formulate a design philosophy for producing an alloy with good mechanical properties over an exceptionally wide temperature range, based partly on an accumulation of empirical knowledge concerning dispersion-hardened alloys and partly on established theory. They specify the microstructural features called for by this design philosophy, and then predict how they may be achieved. The alloy is simple enough: a 90 per cent Ni/10 per cent Al matrix is made by sintering the constituent powders, slightly oxidized. The alloy contains both some γ' phase (ordered Ni₃Al) and some finely dispersed alumina. The achievement of the desired structure is confirmed not only by conventional electron microscopy but also by the new photoemission electron microscope.

This article is not written with all the clarity one might desire, but nevertheless is both instructive and enjoyable.

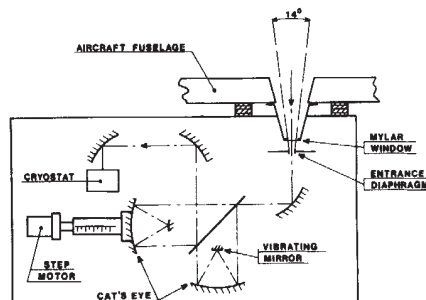
Infrared Observations of the Stratosphere

OBSERVATIONS from a Caravelle aircraft which extend spectroscopic observations of the Earth's upper atmosphere to the range 25 to 200 cm⁻¹ are reported in next Monday's *Nature Physical Science* (February 5). Previous studies of this kind have been restricted chiefly to the region 5 to 125 cm⁻¹.

The instrument—shown schematically in the figure—scans the sky through a 40 μ m mylar window, and contains a detection element consisting of a germanium-doped bolometer at a working temperature of about 2 K. The spectra obtained show good consistency on different flights; the most prominent features are due to H₂O rotational lines, O₂ triplets and the Q_R head branches of O₃.

Baluteau and Bussolletti, reporting this work, have also made assignments corresponding to CO, N₂O and

NO transitions, because these are among the more common of the atmospheric trace gases. Some of these assignments are tentative, but there is good agreement with studies carried out at other frequencies.



Plan of the experimental system flown on the Caravelle to obtain high resolution spectra of the stratosphere between 30 and 200 cm⁻¹.

It has something of the flavour of a nineteenth century scientific paper; one has the sense of the authors thinking out some of the contributory details as they write, instead of pretending throughout, as one is apt to do, that they have magisterially foreseen everything from the start. Their metallurgical achievement, experimentally simple but conceptually subtle, is quite sufficient for them to dispense with claims to omniscience.

QUADRUPOLE COUPLINGS

Nitrogen Measured

from a Correspondent

ALTHOUGH nitrogen quadrupole couplings have been known for many years, a recent report by Blinc and his colleagues in Ljubljana (*J. Chem. Phys.*, **57**, 5087; 1972) demonstrates a new technique for their measurement and applies it to a number of bases such as uracil and amino-acids like cystine. When fully developed, the technique could mean much more sensitive measurements on solids. (Measurements on nitrogen-14 have always been difficult because of its small magnetic moment and the consequent weakness of the detected signals. In the 1950s Dewar used to complain that he had difficulty distinguishing genuine signals from the effects of the underground trains below Queen Mary College, London.)

The importance of nitrogen in natural organic compounds needs no stressing. But whereas n.m.r. studies on protons and carbon-13 signals are very informative, the existence of the quadrupole coupling with nitrogen-14 broadens all the resonance lines in solution and makes a simple n.m.r. experiment so unrewarding that most studies are based on the resonance of nitrogen-15, a sparse isotope with a spin of 1/2 and no quadrupole moment which usually needs enrichment. But when the nitrogen-14 quadrupole coupling can be measured in solids the results are very sensitive to chemical structure and bonding.

The quadrupole couplings depend both on the distorted, non-spherical shape of the nucleus and on the electric field gradient, which reflects the spatial distribution of the valence electrons. Results are expressed in terms of a frequency parameter, $h^{-1}eqQ$, and an asymmetry parameter, η , which measures the lack of axial symmetry. The values of $h^{-1}eqQ$ range from 0 to 7 MHz or higher, and typical of the chemical sensitivity are the values for the para diazine, pyrazine, which has $h^{-1}eqQ=4.857$ MHz and $\eta=0.536$; this differs considerably from the values for the meta compound, pyrimidine, where $h^{-1}eqQ=4.436$ MHz and $\eta=0.386$. These parameters are sensitive to environment and especially to hydro-

gen bonding. If the sensitivity of measurement can really be improved to the point where routine measurements are convenient, the importance for organic chemistry and biochemistry might be considerable.

The technique used by Blinc *et al.* is based on the double resonance schemes introduced by Hahn (*Phys. Rev.*, **128**, 2042; 1962; and **166**, 332; 1968). The sample spends some time in a magnetic field just large enough for the nitrogen-14 resonance, with its quadrupole contribution, to be equal in frequency to that of the protons in the same field. A flip-flop relaxation process can then operate and affect the spin level populations in such a way that any unbalance of the nitrogen-14 populations is shared

with the protons. The sample then reaches a high magnetic field and the proton unbalance is examined with the high sensitivity appropriate to protons. Whether or not the nitrogen-14 populations are unbalanced depends on whether the frequency of a strong radio-frequency transmitter was or was not tuned to resonance with the quadrupole interval that is to be determined. Consequently a proton signal detector is sensitive to the nitrogen resonance.

The special importance of the particular scheme used by Blinc and his colleagues, however, is that the quadrupole resonance condition is met in zero magnetic field and so a powder or disordered solid is as useful as the single crystal required in other cases.

Newfoundland Ophiolites and Plate Tectonics

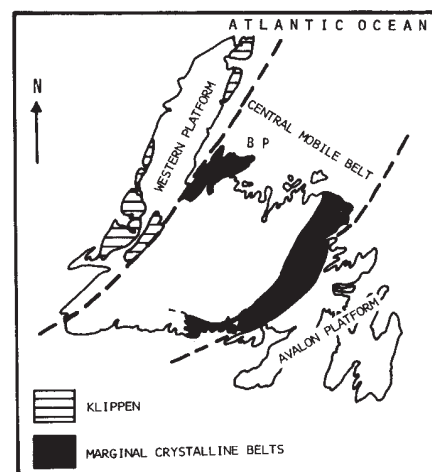
IN next Monday's *Nature Physical Science* (February 5) the usefulness of ophiolites in unravelling pre-Mesozoic plate motions is again demonstrated, this time by Kennedy who deals with the Burlington Peninsula region of Newfoundland. The Appalachian system in Newfoundland comprises three major provinces (see diagram)—the Central Mobile Belt with its thick variably deformed late Precambrian volcanic and sedimentary rocks and, on each flank, stable platforms overlying similar rocks but which are thinner and less deformed. The Central Mobile Belt itself may then be divided three-fold—an axial region which comprises chiefly Ordovician and Silurian sedimentary and volcanic rocks which are moderately deformed and incipiently metamorphosed, and two marginal belts which comprise polydeformed meta-volcanic and metasedimentary rocks of pre-Ordovician age containing major recumbent folds.

The area of particular interest to Kennedy is the northwestern part of the Central Mobile Belt which, with the Western Platform, has been interpreted as a late Precambrian-early Palaeozoic continental margin. Unfortunately, as Kennedy points out, all plate tectonic interpretations carried out so far suffer from being unable to explain the pre-Ordovician polydeformation in the western marginal crystalline belt, for the ophiolite sequences in this area have usually been regarded as Lower Ordovician and so their later displacement and transport cannot be related to the polydeformation.

From a reinterpretation of the structural relationships in the western marginal crystalline belt, Kennedy concludes that there are two ophiolite sequences of different ages; thus although one is undoubtedly Lower Ordovician, as previously thought, the

other is pre-Ordovician. The older sequence is structurally complex, apparently lacking the simple characteristic ophiolite structure, and is interpreted as the remains of a small ocean basin which closed and had its ophiolites obducted before the Ordovician. The polydeformation is then taken to reflect periodic movements in the closure-obduction process. All this predates the formation of the second sequence of ophiolites which were presumably produced by later seafloor spreading and thrust up to their present position by later obduction. In this case no ocean basin closure was involved and so there was no transmission of stress through the adjacent rocks and hence no deformation.

In this way Kennedy is neatly able to solve a local problem. As he points out, however, the solution is really of more than local importance because "it provides the basis for relating some metamorphic nappe complexes in linear orogenic belts to plate movements".



The tectonostratigraphic divisions of Newfoundland. BP, Burlington Peninsula.

SOLAR SYSTEM

Celebrating the Birth of Copernicus

by our Astronomy Correspondent

It is fortunate for the organizers of celebratory conferences that the quincentenary of the birth of Copernicus comes at a time when the study of the solar system and planets is in a healthier state than ever before, even though the end of the Apollo programme has left many selenologists less cheery than is seemly for scientists with so much unanalysed data still up their sleeves. After all, only a few weeks ago an article in *Science* reported the bemoanings of staff at the Manned Spacecraft Center, who apparently have more lunar material than they know what to do with. Had the Copernicus quincentenary occurred only fourteen years ago, before the Lunik flights that is, the celebratory symposium held by the Royal Society and the Royal Astronomical Society in London last week would have dealt with the work of a few dedicated scientists, far removed from the modish astronomy of the day, struggling to glean what they could by peering at objects which from the Earth are only a few seconds of arc in diameter (for example, Mars, 25 arc s) or at best 30 minutes of arc in diameter (the Moon).

Things are different now, as Professor S. K. Runcorn (University of Newcastle upon Tyne) made clear in his review of knowledge of the Moon, which was founded for the most part on information which has come from the Apollo missions and the preceding Orbiter series of automatic lunar satellites (the Orbiters relayed back to the Earth enough detailed photographs of the Moon to keep selenologists busy for years). For example, Professor Runcorn suggested that the moonquakes which have been identified by the seismic network on the Moon as occurring at the edges of the circular maria may arise as a result of the slow sinking of material into the Moon at these locations. According to Professor Runcorn, the existence of this slowly-settling material is suggested by the presence of the gravity anomalies at the circular maria (the mascons, identified by analysis of the motions of Orbiter spacecraft). He suggested that these mascons arise after the circular mare basin has been punched out of the surface by the impact of a meteorite, and after the basin has been filled with lava from below. The solidification of the lava pool leads to a fall in the level of the surface by about 2 km, and it is the further molten material which has welled up from below to fill this 2 km which is the cause of the anomalous

gravity, while the gradual sinking of this circular plug of material gives rise to some of the moonquakes.

But Professor Runcorn could offer no evidence bearing on the question of the origin of the Moon, which, he said, is still largely a matter of taste, although he prefers the view that the Moon accreted from a cloud of dust around the Earth.

Venus and Mars were dealt with by Professor R. Goody (Harvard University) who said that some kind of consensus is now emerging on several topics to do with these planets as a result of the American and Soviet space programmes, ground-based observations, and theoretical work by geophysicists. He said that the investment in this work of a small proportion of the budgets of the American, Soviet and European space programmes will ensure continuing revolutionary discoveries.

Compared with the Earth, Mars and probably also Venus are gravitationally rough, indicating the existence of strong tectonic processes. Professor Goody recited the important discoveries on Mars made by Mariner 9, which include the largest volcano in the solar system (Nix Olympica, which seems to be at least 10 km high, and perhaps even higher), an enormous canyon with dendritic features (Coprates, which among other reasons is odd because there is no sign of any debris which might have been expected to be left behind), and features resembling desert washes which must have arisen by the flow of a liquid over the Martian planes.

The cameras also snapped one of the Martian moons, Phobos, which, of course, can have no atmosphere or internal processes to wipe its surface clean of craters because of its small size. Its crater density, a hundred times that of the Martian surface in general, should therefore be a useful calibration mark for studies in which the ages of Martian surface features are estimated from the density of craters.

As a meteorologist, Professor Goody was obviously not too disturbed by the dust storm which at first hid the Martian surface from the cameras. He conjectured that a mechanism not unlike that of a tropical hurricane could pump the atmosphere of Mars full of dust in a matter of days, and said that some of the photographs towards the end of the storm show features reminiscent of a terrestrial cold front. Professor Goody concludes from his study of the Martian atmosphere that seas might have existed there at an earlier epoch, so

that Mars ought to be examined for fossils.

Jupiter and Saturn have not been studied by space probes, although Pioneer 10 is now across the asteroid belt and should reach Jupiter toward the end of this year, so Professor R. Hide (Meteorological Office) was limited to ground-based information in his talk, although the radio emission from Jupiter is a useful phenomenon which no other planet can match. It seems that the emission can be divided into three classes—thermal emission from the disk, decimetre radiation which comes from an area much larger than the disk and is assumed to have a synchrotron origin, and decametre radiation which appears in bursts apparently controlled by the position of the satellite Io and which comes from areas much smaller than the disk.

Professor Hide is also a meteorologist and much of his talk was a discussion of the atmospheres of Jupiter and Saturn, in particular the Red Spot of Jupiter which has a history going back three centuries, whereas with other similar-sized features in the Jovian atmosphere seem to come and go in a matter of weeks. Professor Hide still seems to favour the view that the Red Spot is a Taylor column depending for its existence on an interaction between the atmosphere and some kind of feature on the surface of the planet (or between the atmosphere and a solid object floating in it).

Copernicus's own field of planetary motions was discussed by Dr G. A. Wilkins (HM Nautical Almanac Office). In particular Dr Wilkins discussed the strange relations which occur between the periods of the outer planets, and between the periods of their satellites. For example, five periods of Jupiter are equal to 2.013 periods of Saturn, three periods of Saturn equal 1.052 periods of Uranus, and two periods of Uranus equal 1.020 periods of Neptune. Similar commensurabilities occur among the satellites of Jupiter and Saturn (indeed, in the case of Saturn the relations extend to some features of the ring system). A full explanation of these phenomena is still not available—questions such as how the regularities arose, and whether they strengthen the system or will eventually lead to the system breaking up, need to be answered—but it seems that tidal friction must be the chief mechanism.

Dr Wilkins also discussed Ovenden's "Principle of Least Interaction Action" by means of which Ovenden has come to some conclusions about the nature of a missing planet in the asteroid belt (*Nature*, **239**, 508; 1972), and although the full details have yet to be published Dr Wilkins feels that Ovenden's principle may turn out to be useful in planetary mechanics.

The AEC and the Loss of Coolant Accident

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Professor Wilson gives the background to the concern being expressed about the risks associated with the possible loss of coolant from a nuclear reactor.

ONE of the chief worries associated with a nuclear power station is the possible accidental release of large quantities of radioactivity. The fact that part of the energy release is in the form of radioactivity creates a unique hazard, which can exist even in the absence of an explosion. This radioactivity persists long after the nuclear fission has taken place; Fig. 1 shows the fission product radioactivity produced by a typical nuclear power station after running for an infinite time at 1,000 MW (electrical) (=3,000 MW (thermal)). Immediately after switching off, the power is still 250 MW, and there is 10,000 million curies (Ci) of radioactivity. Under ordinary circumstances it is obvious that this radioactivity is contained, for nuclear power stations actually exist. Although some release nearly 10^6 Ci a year, radiation doses near them are measured to be small. But the accident problem remains.

It now seems probable that the worst possible accident from the point of view of the exposure of the public to radiation is not a runaway nuclear reaction, but a loss of reactor coolant accident (LOCA), which has received much public attention recently in the United States. The purpose of this article is to illuminate the technical problems, although more lengthy reviews are now available¹.

All nuclear power stations at present operate as steam generating power stations. The higher the temperature of the steam the greater the efficiency. A typical nuclear power plant operates with steam at 600 K, and gives a theoretical Carnot cycle efficiency of 50 per cent and a practical efficiency (using a Rankine cycle) of about 33 per cent. At this temperature water is at a high pressure in the boiler. In the reactors cooled and moderated by water, the reactor vessel must also be at this pressure.

This means that a catastrophic accident could take place if a failure occurs in the reactor vessel or steam piping. The water/steam mixture would leave the reactor (blow-down); even if the break were above the reactor vessel the

superheated water would mostly boil away leaving the core uncooled. The nuclear reaction would cease as soon as the moderator disappeared, but Fig. 1 shows that heat would still be produced at a rate of 250 MW in a typical reactor core of 1,000 foot³.

If no steps were taken to re-establish core cooling, the core would melt. The subsequent course is unclear. An Atomic Energy Commission task force outlined in 1967² several possibilities. In a few minutes the molten core would fall to the bottom of the reactor vessel; in half an hour it would melt the 6-inch thick steel vessel; in a day or two it would melt through the concrete "secondary containment" vessel; finally (in about three months) it would solidify several hundred foot underground. This is, for obvious reasons, called (in the West) the China syndrome. No one knows what would happen to the radioactive fission products, a quarter of which—xenon, krypton and iodine—are gaseous and would certainly not be contained by a molten ball of liquid, although the "secondary" containment might be intact. If cooling is attempted after meltdown has occurred, various mechanisms can be postulated by which the uranium, with even the non-gaseous fission products such as strontium-90, could be spattered over the power station and maybe over the countryside too. The course of events after such a release of radioactivity is also uncertain³⁻⁵. Under favourable meteorological conditions no one would be hurt; under unfavourable ones, a wind of 6.5 m.p.h. with a temperature inversion, the radioactivity would stay close to the ground and thousands of people could die. Fortunately some hours are available to allow evacuation, which is more warning than for a large earthquake, tidal wave or dam failure.

It is hard to predict the likelihood of failure of a steam system. The reactor vessel itself is six inches thick and it is believed, but not absolutely proved, that it could not fail catastrophically; connecting pipes of diameter up to 30 inches could, however, fail. Accordingly, all the reactor safety criteria specify the best materials for the reactor vessel and pipe. The welds in the pipe are X-rayed and tested ultrasonically; moisture detectors are used to detect small leaks before they enlarge to become dangerous breaks.

Catastrophic breaks have occurred in other places, like laundries and fossil fuel plants, where steam pipe of lesser quality is used under pressure. There is no publicly available listing of such failures, which is an omission on the part of nuclear industry and of the AEC. I would guess the failure probability to be less than 1 in 1,000 power station years for "ordinary" pipe, and 1 in 10,000 for "reactor grade" pipe. As 500 nuclear power stations are projected for the year 2000, this would still be a failure every 20 years, which is too large. Accordingly, emergency core cooling systems (ECCS) are built to re-establish cooling as soon as possible in the event of loss of coolant. These ECCS devices do not depend upon the automatic action of a law of physics but are engineered safeguards and depend upon the reliability of the engineering. This feature already makes critics nervous—especially those critics who, like myself, have problems in making gadgets work.

In the event of a small break in water piping, pumps start and resupply water very quickly. It is the large break

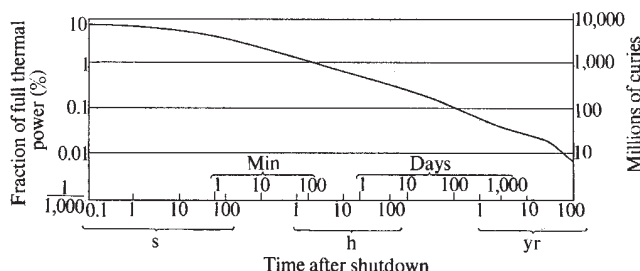


Fig. 1 Radioactivity and fraction of full power from infinite irradiation in a large reactor of 1,000 MWe.

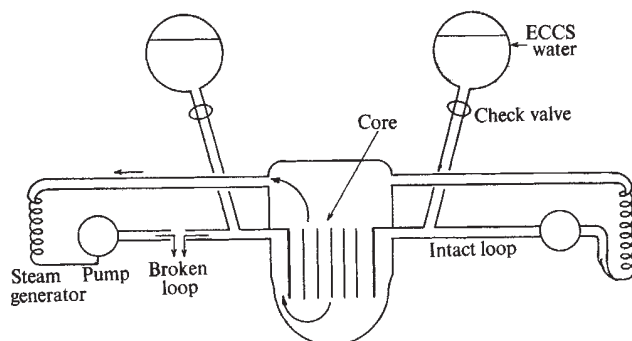


Fig. 2 A schematic drawing of a two-loop PWR showing steam/water mixture leaving a double-ended guillotine break, illustrating flow stagnation in the centre of the core.

that is the problem, and the AEC design criteria assume that on-site power is lost simultaneously with the accident, and that emergency diesel generators must be used. The diesel generators can start and take load in 25 s, and 30 s is assumed. This is not considered to be fast enough for pressurized water reactors (PWR), and large pressurized water tanks (accumulators) are available to inject water (borated to inhibit a nuclear reaction) as soon as the pressure falls sufficiently to allow a check valve to open.

Fig. 2 shows the details of the cooling system of a PWR, which is the type of reactor most subject to criticism. Hot pressurized water passes from the top of the core, through a heat exchanger (steam generator), through a pump, and back to the bottom of the core. The core is made up of 36,000 fuel rods, each 16 foot long and 0.5 inch in diameter, in an open arrangement of 16×16 bundles. The rods are zirconium alloy (zircalloy) tubes filled with pellets of uranium dioxide (UO_2) ceramic. Initially the zircalloy "cladding" has the temperature of the coolant, 600 K. Because it reduces capital expense to use a compact core, the centre of the fuel in the hottest rods is run at as high a temperature as possible—2,500 K—which is just below the melting point of UO_2 .

In a LOCA, the steam/water mixture leaving the core may cool the core for some seconds. During this time the heat stored in the UO_2 will be transferred by conduction to the cladding and removed. But in a PWR it is possible, as illustrated, to envisage a break in such a place that steam leaves the core from both top and bottom, leaving a stagnation point in the middle of the core where there is no flow. If this stagnation point were to be established at the hottest point in the core, the temperature would rise to about 1,400 K before the inside and outside fuel temperatures would be equalized, and after that would rise at 10 K a second because of decay heat.

Elaborate computer programs have been written to describe this blowdown in detail, and, as shown in Fig. 3, these predict flow oscillations and appreciable cooling⁶. There are two coupled parts to the program: the evaluation of the core flow, and the heat transfer. Both have been compared with model tests, but for theoretical reasons the heat transfer coefficients are in doubt. In ordinary operation, heat can be transferred to the water by nucleate boiling, as applies, for example, to a pan of boiling water. Heat is removed very rapidly by this method. But if water is brought to a hot, dry, vertical surface, film boiling can occur in which a steam film forms, through which heat must then be transferred—for this type of boiling, the heat transfer coefficient is 10,000 times smaller. Moreover, heat transfer coefficients are derived from small-scale measurements, and it is not completely clear how these may transform to large-scale geometries. Therefore, if a stagnation point can occur, even for a fraction of a second, it is pru-

dent—and required by the AEC—to assume an immediate switch to the lower heat transfer coefficient for film boiling.

This large change in heat transfer coefficient leads to problems in experimental determination of the coefficients. Neither type of boiling is calculable theoretically. It is, however, believed that heat transfer is dependent on fluid flow and quality (amount of steam) through dimensionless parameters such as Reynold's number and Prandtl's number, and only implicitly dependent on the geometry. The experiments use a few rods in simple geometries, and it is hard to be sure that film boiling is achieved, for any turbulence can lead to rewetting of the surfaces, with a consequent rapid increase of heat transfer. This might indicate that experimental numbers should be used whether or not film boiling is achieved; critics argue, however, that in larger geometries the fluid might preferentially avoid the "hot spot", leading to stagnation. Therefore, although all model tests so far indicate excellent cooling during blowdown⁷, this may mean nothing for a reactor.

The computer programs could be checked by blowdown measurements on a large reactor. Accordingly, in 1963 the loss of fluid test (LOFT) reactor was begun by the Idaho Nuclear Corporation (now Aerojet Nuclear Corporation) for the AEC. This large scale test is seriously delayed and will not be ready until 1975. Meanwhile, there are partially scale systems tests which examine parts of the phenomena.

When the blowdown is in progress, water injected into

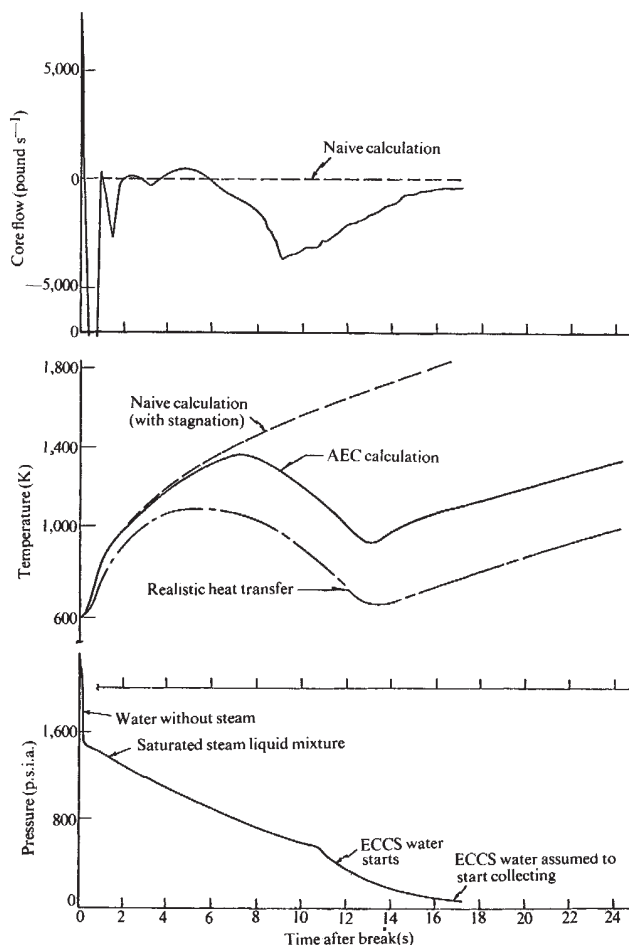


Fig. 3 The water/steam flow for a large break in a real power station (Indian Point 2, Buchanan, NY) and the temperature of the hottest spot in the core calculated using AEC approved heat transfer coefficients. Note the predicted heat removal during blowdown.

the reactor vessel might be hindered by the outgoing steam (steam binding). In "semi-scale" tests (about a tenth the size of a real reactor) water failed, however, to stay in the test vessel although cooling of the electrically heated test rods was good⁸. This rejection of the emergency coolant was unexpected and alarming; the reactor manufacturers' computer programs explained this result after the event, and they say that it will not happen in a real reactor. But the interim AEC regulations insist that it be assumed that no water stays until the blowdown is over (the steam flow stops).

As the incoming water meets the hot zircalloy surfaces, steam will be produced. This steam must escape from the reactor, and it will carry with it entrained droplets of water, reducing the filling rate. There are two paths for the escape of steam; one through the broken loop—direct to the break—and the other through the intact loop, past the incoming ECCS water injection to the bottom of the reactor and from there to the break. The resistance to steam flow can reduce the injection somewhat, particularly if the incoming water "plugs" one of the pipes. The filling rates were measured in a set of tests of small rod assemblies (Full Length Emergency Core Heat Transfer or FLECHT tests) which were difficult to perform because of the high temperatures involved and were not very precise. Some scale tests on pipe plugging are commercial secrets; a few tests have been carried out on steam binding but none in a large reactor.

Another problem, which is probably less serious, arises from the effects of high temperatures on the zircalloy fuel cladding. During the blowdown the heated zirconium cladding will heat, expand and finally burst because of internal pressure at temperatures between 1,000 K and 1,300 K⁹. These bulging tubes can block coolant flow, but no one knows for sure how much, for the core has an open structure and water should be able to get around. Moreover Fig. 4 shows that there are control rod tubes which stay cold.

These uncertainties would be unimportant if the temperature in a LOCA could safely reach the melting point of the ceramic UO_2 at 2,950 K, or even the melting point of zircalloy at 2,100 K; then the rods could lose heat to each other and to the cold parts of the vessel by radiation—which varies as T^4 . But zircalloy has an exothermic reaction with steam, which becomes important above

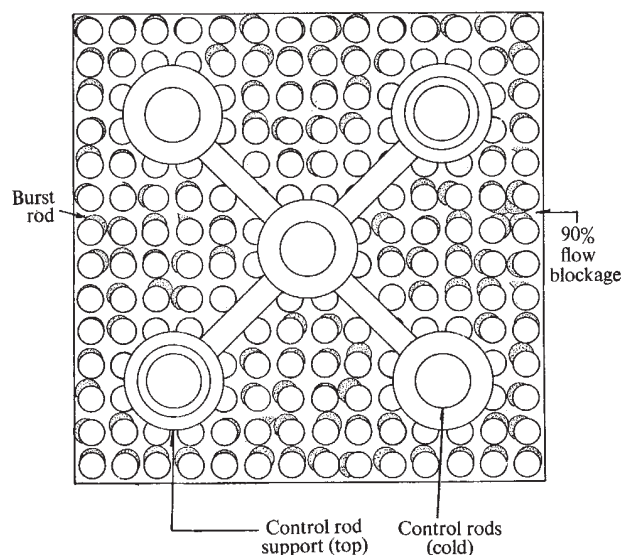


Fig. 4 A section through a PWR fuel bundle, showing spaces for control rods, and possible flow blockage.

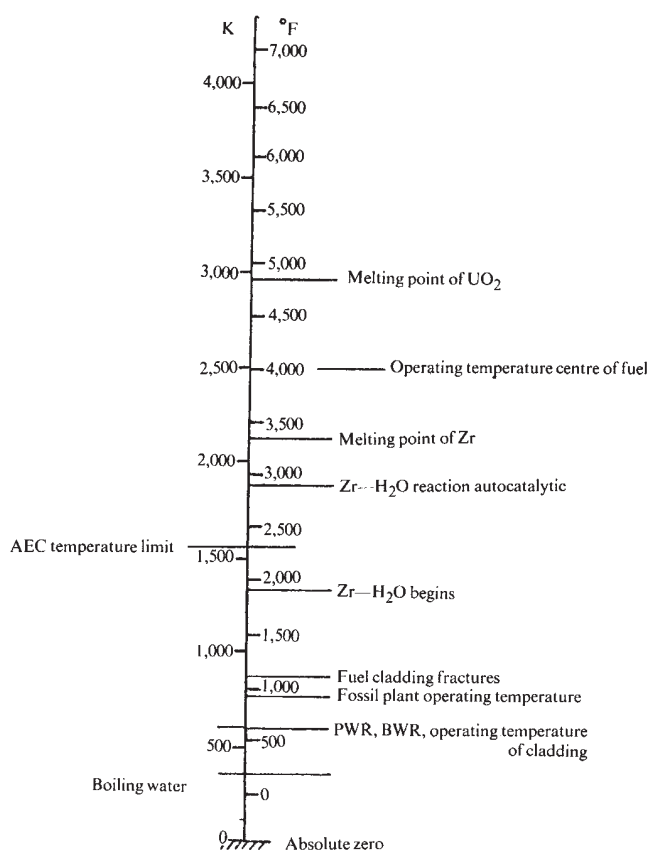


Fig. 5 Critical temperatures in reactor operation.

1,200 K. Above 1,900 K cooling water heats up the cladding instead of cooling it, and oxidizes it. Oxidized cladding becomes brittle on cooling, and can collapse causing more drastic blockages to flow. This happens particularly rapidly if the cladding has expanded, or if steam gets to both sides of a burst tube.

If a reactor were operated at a low power level, say 60 per cent of current designs, the uranium temperature would be lower and the heat stored in the core much lower, particularly as the specific heat of UO_2 ceramic rises with temperature. It is easy to show that ECCS water would be adequate even if no heat were removed during blowdown; at the lower power, steam binding would also be less important.

In 1971 some critics outside the AEC¹⁰ and some inside it¹¹ recommended that the large reactors coming up for licensing should be restricted to a low power level until the LOFT tests are performed. This would be more logical than a complete moratorium proposed by others¹². The AEC chose to restrict reactors less than this, and in June 1971¹³ promulgated interim acceptance criteria for emergency core cooling systems. These limited the calculated temperature to 1,600 K with supposedly conservative heat transfer coefficients and power distribution.

So began a series of procedural errors by the AEC. The interim criteria were not accompanied by an explanatory white paper. Industry, who make both the problems and the profits, did not help. The PWR manufacturers keep even their safety information proprietary to get an edge on their competitors and not even a non-proprietary version of their report¹⁴ was available for six months^{15,16}.

Critics, both friendly and unfriendly, felt that a central public hearing was necessary to enable the best talent to discuss this question instead of having it discussed with inferior talent at every separate hearing for a power station licence¹⁷. The AEC agreed to a hearing in November 1971

and finally presented its written hearing testimony in December 1971. In doing so, the AEC made two more mistakes. Already, on June 30, 1971, the budget of two of the AEC's reactor safety research laboratories had been cut following the desire of Congress to "force" the reactor vendors to pay for safety research. These laboratories, Oak Ridge National Laboratory and Aerojet Nuclear Corporation, act as devil's advocates for the AEC in its dual role of promoting and regulating the nuclear industry. Next they were asked to change their roles and to defend the AEC's interim criteria. As anyone should have expected, their testimony raised all the criticisms noted above, and tended to suggest that the budget reductions were foolish, and that their role as critics is vital.

A logical procedure for safety hearings might be for the reactor vendors (who design the ECCS systems) to present the case that reactors are safe; the AEC's devil's advocates could criticize and demand proof at every stage, with aid from the concerned public (now grouped in the Consolidated National Intervenors) and the AEC's regulatory staff could have been waiting in the middle—as indeed they had been the previous year when these arguments were going on in private. Instead, the AEC's interim criteria were made the subject of the hearings, thus destroying whatever logic had been present in the AEC's administrative stance.

During the first two months of the hearing (February and March 1972) the lawyer for the Consolidated National Intervenors (Mr Myron Cherry), aided by a young economist from Harvard (Daniel Ford), with MIT physics professor Henry Kendall in the background, tried to prove that these criteria are arbitrary and capricious; an easy task since regulations are, by their nature, arbitrary. They found inevitable disagreements between a hundred witnesses from the AEC staff, ORNL and ANC. P. Rittenhouse of ORNL wants to replace the simple temperature limit of 1,600 K by a calculation of oxidation and embrittlement and Dr L. Ybbarrondo of ANC believes that the heat transfer coefficients may not be adequately conservative, and blow-down flow rates may be lower than calculated in the region of the hot spot.

During the summer, the reactor vendors and intervenors presented testimony on which they were cross-examined, and rebuttal testimony was presented in October 1972. Meanwhile the trend towards higher power per unit length in the reactors is halted. The General Electric Company make a boiling water reactor (BWR) whose internal circuits make it less liable to flow stagnation and therefore less liable to criticism. Nonetheless GE have announced a new fuel element of smaller size (seven-eighths of the former). This new fuel element will store less heat; it was designed primarily to prevent cracking at high temperature (as happened at the Dresden II power station in Illinois), but it also will keep down the temperature in a calculated LOCA to 1,100 K—a level which the critics may find acceptable. The fuel fabrication cost is roughly proportional to the number of fuel rods and increases 30%. But it only represents an increase of 2% in the total cost of nuclear power. Westinghouse have also announced a fuel element of smaller size to increase the margin of safety.

In May 1972 (ref. 18) serious defects were discovered in nuclear fuel made by Westinghouse. In three large reactors, BEZNAU, Switzerland; GINNA, New York; and ROBINSON No. 2, N. Carolina, voids have occurred between uranium pellets, and zircalloy tubes (which are susceptible to creep) have collapsed because of the external pressure, like a squeezed toothpaste tube. A collapsed tube leaves more moderator at the point of collapse and this gives a very peaked power distribution with a hotter "hot spot" in a LOCA. Some of these tubes have leaked, but it is feared that many might leak simultaneously with a consequently large radioactivity release. No one knows for sure why the voids appear between the pellets; the pellets are made of

sintered UO_2 of less than the maximum density and they seem to become denser (and shrink) on irradiation. Or the voids might be a consequence of careless manufacture.

The present Atomic Energy Commission chairman, James Schlesinger, is more sensitive to criticisms than his predecessor. The AEC regulatory staff insists that all PWRs with zircalloy fuel operate at reduced power to make up for possible power peaking and possible increased brittleness of the cladding. The General Electric BWR uses a lower pressure and thicker clad and shows no such problem; the other manufacturers must prove that this problem does not occur. Combustion Engineering use thicker clad and denser fuel than Westinghouse, and X-ray each fuel rod to prove the initial absence of voids, but their two reactors are still held at low power pending better proof. Some utility companies are now proposing operating conditions with reduced power peaking and hence greater safety margins.

Such changes may increase the cost of nuclear power stations. If the reactor vendors are right, the reactors are already safe, but it will be more obvious that they are safe. Until recently, nuclear proponents feared that unnecessary cost increases would price nuclear power out of the market, causing more fossil fuel to be burnt with much more air pollution and its attendant death toll. But cost will not now stop nuclear power. Recently the east coast cities in the United States demanded that utilities burn oil of low sulphur content to avoid SO_2 emission; natural gas is not to be had. Because of this the price of fuel oil has risen three-fold (from \$1.75 to \$4.75 a 42-gallon barrel in Boston) in two years. Interest on a high capital cost is less than a high, and increasing, fuel cost.

This increase in fossil fuel prices is likely to continue all over the world as fuel reserves run short. In Britain, for example, the Central Electricity Generating Board has announced that three of the Magnox reactors produced the cheapest electricity last year. This was in spite of the power reduction ordered following the discovery of corrosion of the Magnox fuel in one of these reactors. A similar, temporary power reduction in the United States would have a similar, temporary, and small effect.

¹ Ybbarrondo, L. J., Solbrig, C. W., and Isbin, H. S., *J. Amer. Inst. Chem. Eng.* (in the press).

² *Emergency Core Cooling, Report of AEC Task Force* (US AEC Report TID 24226, 1967).

³ *Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants* (USAEC Report Wash-740, 1957).

⁴ *A Report on the Possible Effects [of major accidents] at Lagoona Beach, Michigan*, prepared for the Atomic Power Development Associates, Michigan (1957).

⁵ Beattie, J. R., and Bryant, P. M., *Assessment of Environmental Hazards from Reactor Fission Product Releases* (Report AHSB(S)R135 (1970); available from HMSO).

⁶ *Final Safety Analysis Report and Amendments thereto for the Indian Point 2 Power Plant* (Consolidated Edison Co., New York, 1970).

⁷ Report 10015, Suppl. 1 Babcock and Wilcox Co. (Fig. 52, June 1971).

⁸ *Semi-scale Tests 845-851*, Report Hai 125-71 (Idaho Nuclear Corporation, 1971).

⁹ *Nuclear Technology*, 2, No. 4 (August 1971).

¹⁰ Lapp, R., at *Hearing on Acceptance Criteria for Emergency Core Cooling Systems*, AEC Docket RM-50-1 (1972).

¹¹ Colmar, R., and Rosen, M., at *Hearing on Acceptance Criteria for Emergency Core Cooling Systems*, AEC Docket RM-50-1 (1972); *Science*, 176, 492 (1972).

¹² Ford, D., Kendall, H., and MacKenzie, J., *Nuclear News*, 15, 28 (1972).

¹³ *Federal Register*, 36, No. 125, 12247 (June 29, 1971); *Science*, 173, 126 (1971).

¹⁴ *Westinghouse Topical Report*, WCAP-7422 (1971).

¹⁵ Rasmussen, N. R., *Nuclear News*, 15, 35 (1972).

¹⁶ Wilson, R., at *Hearing on Acceptance Criteria for Emergency Core Cooling Systems*, AEC Docket RM-50-1 (1972).

¹⁷ *Testimony before the Joint Committee on Atomic Energy Hearings on AEC Licensing Procedures*, 445 (June 1971).

¹⁸ *AEC News Release* (July 1972); *Science*, 177, 330 (1972).

Function of Lipophilic Acids as Antimicrobial Food Additives

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Most antimicrobial food additives are lipophilic acids which prevent growth by inhibiting the transport of substrate molecules into cells. The inhibition of transport was also observed in membrane vesicles, even when they were derived from organisms for which growth and transport are not affected by the larger inhibitors.

Most antimicrobial food additives (preservatives, Table 1) now in use are lipophilic acids which inhibit the growth of unwanted microorganisms, usually without killing them (exceptions are alkylating agents). They are ingested in significant quantities but do not grossly interfere with the human organ function as judged by toxicity tests. So far their inhibitory mechanism remained unknown². We wish to show here that it results from the inhibition of substrate transport into cells.

Inhibition of Microbial Growth

Preservatives are weak acids whose growth inhibitory effect increases when the pH is lowered from neutrality (except for parabens, with a pK above 8), indicating that inhibition results from the undissociated acid^{2,3} (whose fraction can be calculated from the known pK values, Table 1).

As the inhibitory concentrations of compounds differ greatly, the inhibition index is plotted against the logarithm of the inhibitor concentration in Figs. 1–3. (Index=0 if there is no inhibition and 1 if there is no growth. Values above 1 signify cell lysis.) The concentration of fatty acids (Fig. 1a) or parabens (Fig. 2a) needed to produce a certain amount of growth inhibition of *Bacillus subtilis* (at pH 6.5) decreases with increasing chain length³, saturated and unsaturated fatty acids being about equally effective. Presumably, the more lipophilic long chain compounds are more effectively partitioned into the cell membrane. This membrane attachment is reversible, because when cells, inhibited by fatty acids from acetic to linoleic acid or by propylparaben, are resuspended in fresh medium, growth resumes immediately at the uninhibited rate. Fig. 3a shows that sulphite, nitrite and benzoate inhibit efficiently, while nitrate has almost no effect. 2,4-Dinitrophenol (DNP) is as effective as long chain fatty acids. The antioxidants ascorbate and erythorbate inhibit only at high concentrations.

Inhibition by fatty acids (Fig. 1a), DNP and sulphite (Fig. 3a) increases about ten-fold (from 0.1 to 1) when their concentra-

tion is raised by a factor of 10, indicating an essentially linear concentration dependence. The increase is more rapid for the parabens (Fig. 2a) or nitrite (Fig. 3a).

Fatty acids and propyl parabens inhibit the growth of *B. pumilis*, a close relative of *B. subtilis*, to the same extent (Figs. 1a and 2a). Strains of *B. subtilis* or *B. pumilis* (renamed) produce "rope" in bread, a spoilage which is prevented by the inclusion of propionate^{2,7}.

Mechanism of Inhibition

Compounds which inhibit the polymerization of RNA (actinomycin D) or protein (chloramphenicol) do not inhibit cellular oxygen consumption, while the preservatives do (Table 2). Because *B. subtilis* is strictly aerobic this inhibition entails the depletion of ATP, the concentration of which is reduced by up to 90% (Table 2)⁵.

Although saturated fatty acids inhibit cellular oxygen consumption, they do not inhibit the NADH oxidation by isolated membranes (Table 2)⁸, that is by the cytochrome-linked electron transport system⁶. Therefore, the inhibition of oxygen consumption in whole cells must result from the deficiency of compounds that enter electrons into the electron transport chain. We will show below that this deficiency results from the inhibition of transport of the necessary substrates into cells. Saturated fatty acids inhibit the uptake of serine or α -amino-isobutyric acid in *B. subtilis*⁸, and the uptake of arsenate or phosphate in yeast^{9,10}. Inhibition of cellular

Table 1 Common Food Additives

Antimicrobial food additives*	pK †	Maximal millimolar concentration present in certain foods ‡	Food
Acetate, C ₂ (H, Na, K; di-)	4.76	500	Pickled food
Benzoate (H, Na)	4.2	8	Beverages
Heptyl paraben§	8.47	?	Beer
Methyl paraben	8.47	5	Beverages, jams
Nitrite (Na, K)	3.29	3	Meat
Octanoate, C ₈ (caprylate)	4.88	?	Cheese wrappers
Propionate, C ₃ (Na, Ca)	4.87	100	Cheese
Propyl paraben	8.47	0.6	Creams, pastes
Sorbate (H, K, Na)	4.8	30	Cheese
Sulphite (mono-, bi-, K, Na; SO ₂)	1.8, 7.0	5	Wine

Other compounds used (pK values in parentheses): ascorbate (4.19, 11.57); benzoate (4.20); *n*-butyrate, C₄ (4.82); *n*-decanoate, C₁₀=caprate (4.9); 2,4-dinitrophenol, DNP (4.1); erythorbate=isoascorbate; ethyl-paraben (8.47); *n*-hexanoate=caproate, C₆ (4.87); *p*-hydroxybenzoate (4.58, 9.31); linoleate, C₁₈ (4.9).

* In parentheses are listed the cations with which the compounds are usually added or alternative forms or names of the compounds.

† Data from Jencks and Regenstein¹.

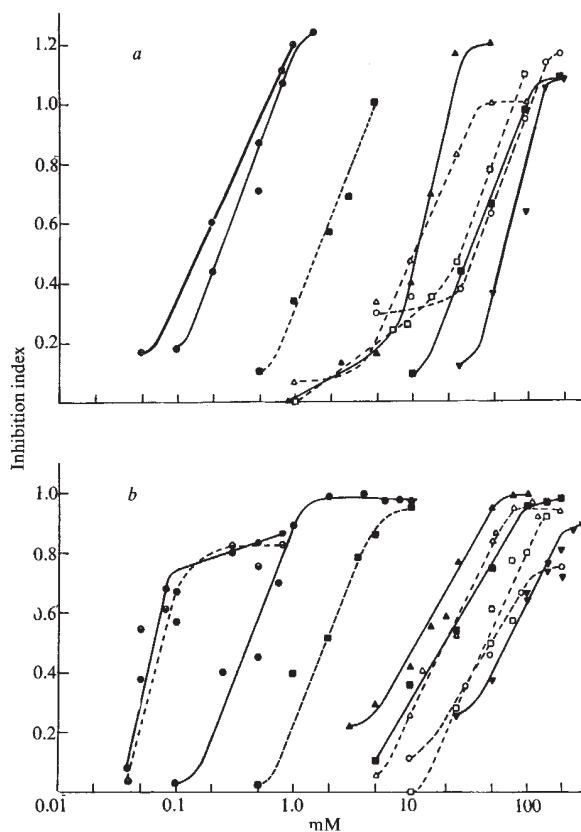
‡ Data calculated from values given by Chichester and Tanner².

§ "Parabens" are esters of *p*-hydroxybenzoic acid.

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Fig. 1 Inhibition by fatty acids of *B. subtilis* growth and of serine uptake in membrane vesicles. Saturated fatty acids are identified by the number of carbon atoms (C_2 =acetate, C_3 =propionate, C_4 =butyrate, C_6 =hexanoate=caproate). *a*, Growth: *B. subtilis* (60015, requiring methionine and tryptophan) was shaken at 37° C in nutrient medium (buffered at pH 6.5 by 0.1 M phosphate)⁴ to $A_{600}=0.5$. Aliquots were transferred to prewarmed Erlenmeyer flasks or large test tubes containing different amounts of the inhibitor (dissolved in water or ethanol). The same solvent was present in the control flasks. Using the difference ΔA between the A_{600} at 1 h and that at zero time for the experimental flasks and the corresponding value ΔA_c for the control flask, an inhibition index $= 1 - \frac{\Delta A}{\Delta A_c}$ was calculated.

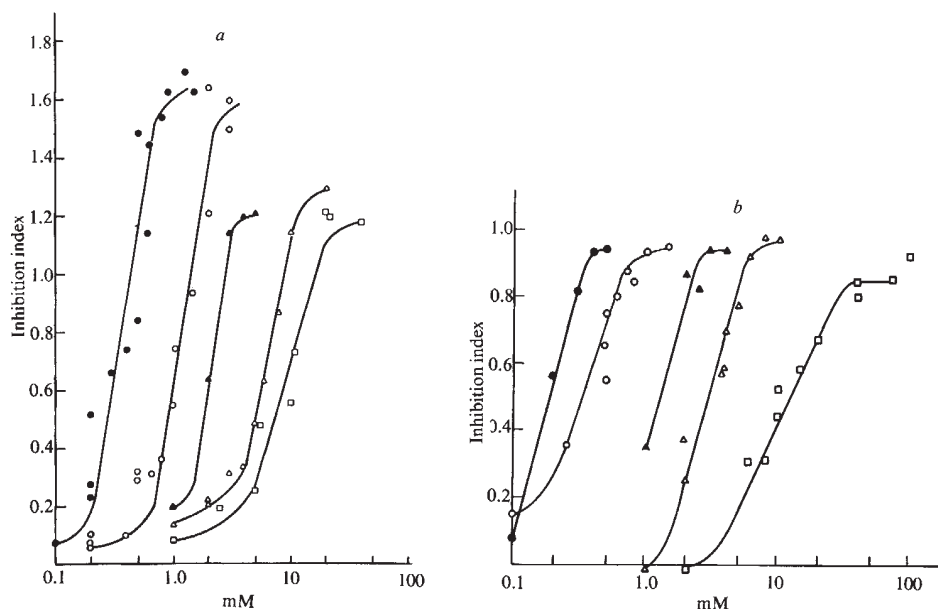
The short chain fatty acids (up to C_6) were used as potassium salts dissolved in water, at pH 6.5, while the long chain fatty acids were dissolved in ethanol and used in the buffered medium at low enough concentrations that the pH remained 6.5. The same extent of growth inhibition was observed with the prototroph *B. subtilis* strain (60009)⁵ and also with *B. pumilis* (strains ATCC 4520, 4522, 6631) for acetate, propionate, butyrate, hexanoate, decanoate and sorbate. *b*, Serine uptake: membrane vesicles of *B. subtilis* (60015), grown in nutrient medium plus 10 mM glycerol (to induce glycerol-phosphate-dehydrogenase) to $A_{600}=1$, were prepared and tested (in 100 μ l. final volume) for serine uptake in the presence of α -glycerol-phosphate as energy source, according to Konings and Freese⁶. The fatty acid (potassium salt in water or free acid in ethanol or dimethyl sulphoxide, final solvent concentration maximally 1%) was added to the reaction mixture containing the vesicles (1 mg ml.⁻¹ protein) and incubated at 25° C for 1 min before addition of glycerol-phosphate (20 mM) and ¹⁴C-L-serine (15.6 μ M). Three minutes after serine addition the reaction was stopped by 2 ml. 0.1 M LiCl (25° C) added to a 'Millipore' filter (pore size 0.45 μ m) and washed twice with 2 ml. LiCl. The zero time values were obtained by adding the serine after the LiCl. Inhibition index $= 1 - \frac{\Delta U}{\Delta U_c} \approx \frac{U_c - U}{U_c - U_c^0}$ where U and U_c are uptake values after 3 min and U_c^0 is the uptake value of the control (or the fatty acid containing) sample at zero time. $\ominus$ — $\ominus$, Linoleate; $\bullet$ — $\bullet$, C_{10} ; $\blacksquare$ — $\blacksquare$, C_8 ; $\blacktriangle$ — $\blacktriangle$, C_6 ; $\blacksquare$ — $\blacksquare$, C_4 ; $\circ$ — $\circ$, C_3 ; $\blacktriangledown$ — $\blacktriangledown$, C_2 ; $\triangle$ — $\triangle$, sorbate; $\square$ — $\square$, crotonate; $\ominus$ — $\ominus$, oleate.



uptake, however, does not necessarily prove that transport itself is inhibited; it may merely reflect the inhibition of metabolism, the unmetabolized compound preventing its own uptake. This objection is less valid for arsenate, whose metabolites are unstable, or for α -amino-isobutyric acid, which is not metabolized⁸. The objection can be generally ruled out by the use of membrane vesicles, which can be obtained from bacteria almost free of cytoplasmic components and whose transport depends strictly on the presence of an added energy source^{6,8,11}. In membrane vesicles of *B. subtilis* the uptake

of L-serine, energized by α -glycerol-phosphate or NADH, is inhibited by short and long chain saturated and unsaturated fatty acids (Fig. 1b), by parabens (Fig. 2b), and by other microbial growth inhibitors (Fig. 3b, and see Table 2). Because the inhibition index in this case cannot exceed 1, the concentration dependence of transport inhibition by different compounds is remarkably similar to that of growth inhibition. The only exception is sulphite, which has only a marginal effect on membrane transport. (Neither sulphite nor nitrite can serve as energy source.) Only high concentrations of

Fig. 2 Inhibition by parabens of (a) growth and of (b) serine uptake in vesicles. Conditions as in Fig. 1. Parabens were dissolved in ethanol. $\bullet$ — $\bullet$, Butyl; $\circ$ — $\circ$, propyl; $\blacktriangle$ — $\blacktriangle$, ethyl; $\triangle$ — $\triangle$, methyl; $\square$ — $\square$, *p*-hydroxybenzoate.



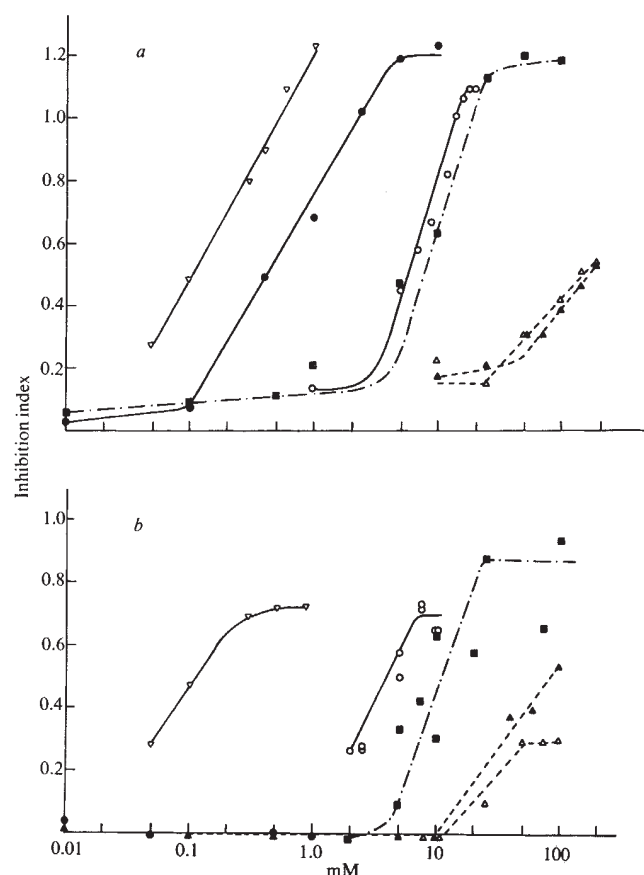


Fig. 3 Inhibition by miscellaneous compounds. *a*, Growth; *b*, serine uptake. Conditions as in Fig. 1. DNP, 2,4-dinitrophenol. The inhibition of growth by up to 50 mM nitrate was less than 3%. ∇ — ∇ , DNP; $\bullet$ — $\bullet$, sulphite; $\blacksquare$ — $\blacksquare$, benzoate. $\circ$ — $\circ$, nitrite; $\triangle$ — $\triangle$, ascorbate; $\blacktriangle$ — $\blacktriangle$, erythorbate;

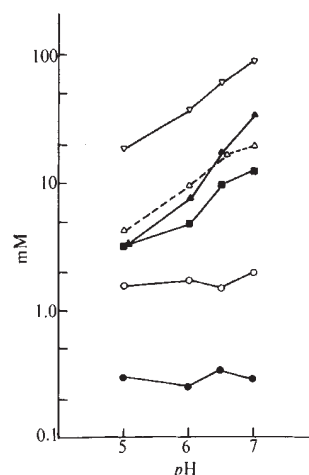


Fig. 4 pH dependence of 50% inhibitory concentration for serine uptake in membrane vesicles. Serine uptake was measured, as in Fig. 1*b*, at different pHs and for different concentrations of inhibitors. The interpolated concentration values that would give 50% inhibition at a given pH are plotted for different pHs. ∇ — ∇ , C₃; $\blacktriangle$ — $\blacktriangle$, C₆; $\triangle$ — $\triangle$, sorbate; $\blacksquare$ — $\blacksquare$, benzoate; $\circ$ — $\circ$, nitrite; $\bullet$ — $\bullet$, propyl paraben.

ascorbate or erythorbate inhibit membrane transport (these compounds do not energize transport).

The inhibition of active transport can be observed also for other amino-acids such as L-leucine, and for L-malate, whose uptake is also energized by glycerol-phosphate (Table 3). The interpolated concentration needed to inhibit vesicular serine transport by 50% is much lower at pH 5.5 than at pH 7 for propionate, hexanoate, sorbate or benzoate, but not for propyl paraben (Fig. 4), in agreement with the *pK* values. However, the inhibition by nitrite is not dependent on pH, indicating that vesicular transport is inhibited by the negatively charged nitrite ion. As we found, in agreement with published reports², that growth inhibition by nitrite increases with decreasing pH, some other reaction must contribute to the growth inhibition

Table 2 Inhibitory Effects of Different Compounds on Whole Cells and Membrane Vesicles of *B. subtilis*

Compound	Concentration	Growth	Whole cells O ₂	% Inhibition (=inhibition index × 100)				
				ATP	Membrane vesicles Serine uptake		Oxidation	
					α -gly-P	NADH	α -gly-P	NADH
Alcohol	1%	12	0	0	0	10	0	0
Dimethyl sulphoxide	1%	0	ND	ND	0	0	0	0
Actinomycin D	100 μ g ml. ⁻¹	105	0	0	ND	ND	2	0
Chloramphenicol	100 μ g ml. ⁻¹	100	0	0	16	0	25	0
<i>n</i> -Decanoate	0.8 mM	107	85	78	88	72	1	0
Butyl paraben	0.5 mM	150	70	82	95	ND	37	62
Propyl paraben	1 mM	142	74	54	93	ND	26	50
Ethyl paraben	3 mM	80	74	49	95	ND	30	33
Methyl paraben	10 mM	115	62	54	95	ND	20	25
<i>p</i> -Hydroxybenzoate	20 mM	122	68	45	68	ND	46	0
Benzoate	20 mM	101	65	59	57	41	37	0
Sorbate	50 mM	101	80	61	85	61	47	0
Crotonate	80 mM	99	80	69	65	60	33	0
Nitrite	10 mM	66	86	58	78	ND	0	0
Acetate	200 mM	111	76	77	73	ND	0	0
Propionate	150 mM	114	83	68	67	71	0	0
Sulphite	10 mM	123	Aut.	84	0	ND	Aut.	Aut.
Ascorbate	200 mM	55	Aut.	3	44	ND	Aut.	Aut.
Erythorbate	200 mM	53	Aut.	10	80	ND	Aut.	Aut.

Aut. = Autoxidizes too rapidly.

For the inhibition in whole cells, *B. subtilis* strain 60015 was grown⁴ to $A_{600}=0.5$, the cells were distributed to flasks containing the inhibitor, and the subsequent growth response was measured^{5,8}. Without inhibitor the following values were found: exponential growth rate=1.4/h; oxygen consumption (O_2)=293 nmol/(min × A_{600}); ATP concentration (ATP)=2.9 nmol/ A_{600} . Membrane vesicles were prepared from *B. subtilis* (60015) cells grown in nutrient medium⁴ plus 10 mM glycerol (to induce glycerol-phosphate-dehydrogenase). Serine uptake was measured in membrane vesicles (1 mg/ml. protein) with 20 mM α -glycerol-phosphate (α -gly-P) or NADH as energy source as in Fig. 1. Oxidation of the substrates at the same concentrations was determined with 0.1 mg/ml. membrane protein. Without inhibitor the rates of serine uptake were with α -gly-P: 118 pmol/(min × mg protein) and with NADH: 62 pmol/(min × mg protein), while the rates of oxidation were for α -gly-P: 76 nmol/(min × mg protein) and with NADH: 186 nmol/(min × mg protein).

Table 3 Transport Inhibition of Leucine and Malate

Inhibitor	Concentration (mM)	% Inhibition of the uptake of Leucine	Malate
Propionate	150	85	64
Hexanoate	50	93	71
Linoleate	0.2	72	55
Propyl paraben	1.0	96	76

Uptake was measured as in Fig. 1. Without inhibitor the rates of uptake were for ^{14}C -(UL)-L-leucine ($16\ \mu\text{M}$, $5\ \mu\text{Ci ml}^{-1}$); $28\ \text{pmol}/(\text{min} \times \text{mg protein})$ and for ^{14}C -(UL)-K-malate ($0.1\ \text{mM}$, $2.6\ \mu\text{Ci ml}^{-1}$): $208\ \text{pmol}/(\text{min} \times \text{mg protein})$.

at lower pHs. Part of it may be the lethal (and mutagenic) effect whose strength increases with decreasing pH¹².

Specificity of Inhibition

While *B. subtilis* is inhibited by all food preservatives, other microorganisms are inhibited only by some². Growth inhibition of *Escherichia coli* by different saturated fatty acids, for example, is shown in Fig. 5a. About the same concentrations of short chain fatty acids, up to C₆, and DNP, inhibit the growth of *E. coli* as that of *B. subtilis*. But for C₈ about twice, and for C₁₀ about fifty times the concentrations are needed, while no inhibition is observed with long chain fatty acids (Fig. 5a). The uptake of L-serine into *E. coli* cells is also not inhibited by concentrations of long chain fatty acids that completely inhibit growth or serine uptake in *B. subtilis* (Fig. 6). This lack of inhibition is not due to a particular property of the transporting membrane; in membrane vesicles of *E. coli* all fatty acids inhibit serine transport at the same concentrations as in vesicles of *B. subtilis* (Fig. 5b). The effective concentration of long chain fatty acids is apparently lower in the (trans-

porting) membranes of whole *E. coli* cells than in the membranes of isolated vesicles. As a possible explanation for this difference, the long chain fatty acids that are partitioned into the membrane of *E. coli* might be so rapidly metabolized^{13,14} that only much larger concentrations are inhibitory. *B. subtilis* cannot metabolize long or short chain fatty acids, and it can effectively use acetate only at high concentrations ($50\ \text{mM}$)^{15,16}. Alternatively, the lipopolysaccharide layer that typically surrounds the wall of Gram negative organisms could screen out the larger compounds. The latter explanation is the correct one, as will be reported elsewhere.

In contrast to *B. subtilis*, concentrations of the fatty acids (up to C₈) which completely inhibit growth of *E. coli* do not reduce the concentration of ATP/A₆₀₀ (measured after 20 or 40 min incubation). Apparently, some other compound is exhausted before ATP is used up.

Generalizations and Future Studies

Lipophilic acids, including preservatives, somehow uncouple^{8,17} both substrate transport and oxidative phosphorylation from the electron transport system. They apparently inhibit growth principally by inhibiting the cellular uptake of amino-acids, organic acids, phosphate and so on, because in whole cells these two inhibitory phenomena are strictly correlated, whereas the concentration of ATP does not necessarily decrease (in the facultative anaerobe *E. coli*). In contrast to saturated fatty acids and DNP, which only uncouple⁸, unsaturated fatty acids and parabens partially inhibit also the electron transport system itself (Table 2). Exceptional preservatives are sulphite, which does not inhibit transport, and nitrite, for which the inhibition of growth but not of transport increases with decreasing pH.

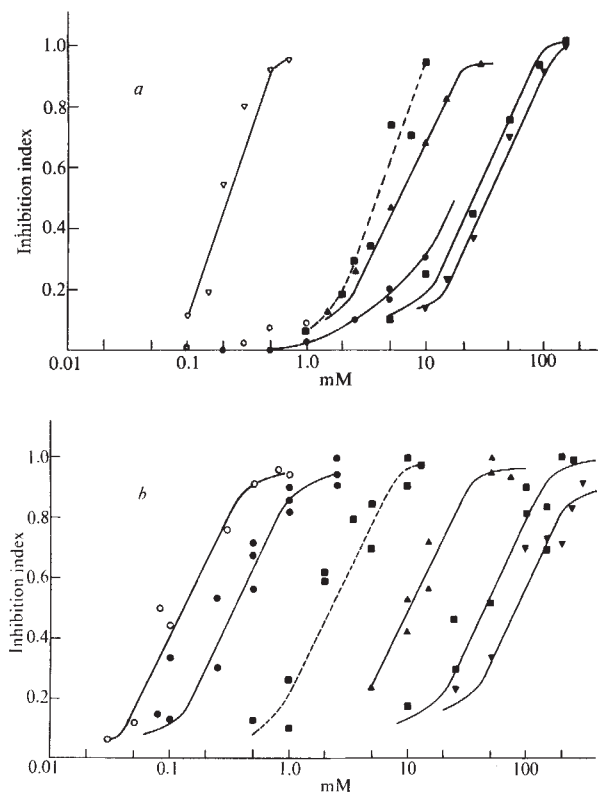


Fig. 5 Inhibition by different fatty acids of growth and serine uptake in membrane vesicles of *E. coli* (strain NF 161, which requires methionine and arginine). Growth inhibition (a) and vesicular transport (b) were measured as in Fig. 1. ∇ — ∇ , DNP; $\bullet$ — $\bullet$, C₁₀; $\blacksquare$ — $\blacksquare$, C₈; $\blacktriangle$ — $\blacktriangle$, C₆; $\blacksquare$ — $\blacksquare$, C₄; $\blacktriangledown$ — $\blacktriangledown$, C₂; $\circ$ — $\circ$, linoleate.

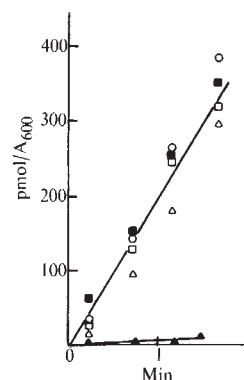


Fig. 6 Serine uptake of resting cells of *E. coli*. *E. coli* cells were grown to A₆₀₀=0.28, washed twice on 'Millipore' filters, resuspended in N medium⁴, and starved for 90 min at 25° C. The rate of ^{14}C -(U)-L-serine ($0.62\ \mu\text{M}$, $0.08\ \mu\text{Ci ml}^{-1}$) uptake was measured⁸. $\circ$, No addition; $\blacksquare$, 5 mM linoleate; $\square$, 0.5 mM linoleate; $\triangle$, 2 mM C₁₀; $\blacktriangle$, 20 mM C₁₀.

Some organisms are resistant to certain lipophilic acids. If the transport comparisons of *E. coli* membrane vesicles and whole cells can be generalized, the resistant organisms seem to prevent the accumulation of the inhibitor on the transporting cell membrane. In any case, the resistance of some (Gram negative) organisms to long chain fatty acids can be used to select for them among sensitive (Gram positive) organisms.

Because membranes of all organisms contain phospholipid bilayers, some antimicrobial lipophilic acids must also inhibit human cells; inhibitors with low pK should be particularly effective in the highly acidic intestinal fluid. A comparison of the inhibition of growth, transport, or nerve function of human cells with that of microorganisms should reveal which preservatives are least harmful to man. For example, it may be possible to replace nitrites and sulphites, which induce mutations^{12,18} and of which nitrite can produce carcinogenic nitrosamines¹⁹, by other inhibitors and colour fixatives which

do not involve the potential hazard of genetic damage on somatic or germ cells.

Received July 14; revised October 20, 1972.

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Boundary between Continental and Oceanic Crust at the Margin of Rifted Continents

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From a detailed study of the continental margin off Norway we have been able to establish the presence of two buried marginal escarpments—Vøring Plateau Escarpment and the Faeroe Shetland Escarpment. We believe that these escarpments together with a segment of the Jan Mayen Fracture Zone between them define quite clearly the boundary between the continental and oceanic basement. We describe these findings and discuss their application to other continental margins.

Two buried marginal escarpments off Norway—Vøring Plateau and Faeroe Shetland (Fig. 1)—define the landward boundary of buried basement highs on the continental slope¹. The basement highs are a direct continuation of the typical oceanic basement which lies seaward. Landward of the basement highs there is a large marginal sedimentary basin in which the maximum sediment thickness exceeds 7 km.

Continental Margin off Norway

Fig. 2 shows a structure section across the Vøring Plateau Escarpment based on velocities obtained from seismic

refraction and wide angle reflexion data. We also show four projected isostatic gravity and residual total intensity magnetic profiles. The sedimentary section northwest of the Vøring Plateau Escarpment is less than 2 km thick and the seismic velocity of the layer overlying basement is about 2.2 km s⁻¹. The oldest identifiable magnetic anomaly northwest of the escarpment is believed to be anomaly 24 (60 m.y. BP, ref. 2) and thus the basement is early Tertiary in age. Southeast of the escarpment there is a large increase in sediment thickness. The seismic velocities in the lower part of the sedimentary sequences are significantly higher than those above Tertiary basement northwest of the escarpment. Although the seismic velocities would be expected to increase with increased thickness of Tertiary sediments, in the adjacent North Sea basin the Tertiary sedimentary section has a velocity almost always less than 2.5 km s⁻¹ even where it is a few km thick. Velocities higher than 2.5 km s⁻¹ in the North Sea have been associated with sediments of Mesozoic and Late Palaeozoic age. We believe that there is a similar velocity-age relationship for the sediments on the Norwegian Shelf. Support for this belief comes from the known occurrence of Mesozoic outcrops on the shelf. The shelf sediments thicken progressively seawards with maximum thickness on the slope. We infer that the marginal sedimentary basin is a continuation of the North Sea basin and has, in addition to the Cainozoic sediments, a thick Mesozoic sequence and probably also a sequence of Late Palaeozoic sediments. Thus there is a significant contrast in age of the basement across the escarpments and most of the sediments in the basin predate the Early Tertiary opening of the Norwegian Sea.

In Fig. 2 we show the pronounced change in magnetic

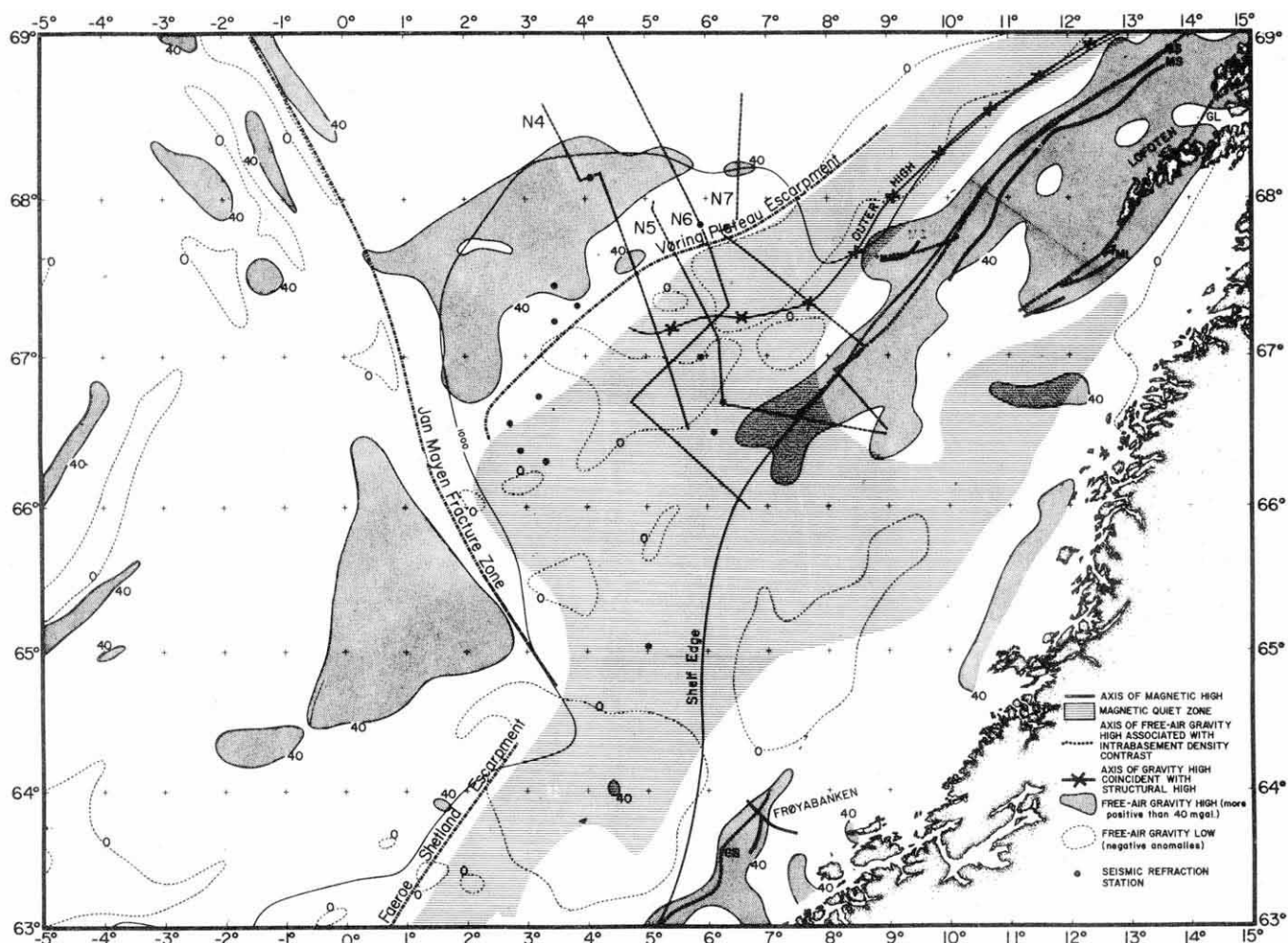


Fig. 1 Prominent gravity and magnetic features of the Norwegian continental margin. We believe that the gravity and magnetic lineations on the shelf are caused primarily by intrabasement density and magnetization contrast, although a small amount of basement relief (~1 to 2 km) also seems to be associated with belts of Pre-Cambrian age. The gravity "Outer High" is believed to be a structural high. Note that gravity lows exist between the shelf edge and the escarpment. The magnetic quiet zone crosses the shelf edge between 64 and 66° N. The 1,000 fm contour is indicated.

anomalies at the escarpment. Seaward the anomalies form linear patterns characteristic of seafloor spreading. Landward the magnetic anomalies are very subdued and constitute a magnetic quiet zone. Between 65° N and 67° N the magnetic quiet zone extends across the shelf edge (Fig. 1). It has been argued that the higher amplitude magnetic anomalies observed seaward of the Vøring Plateau Escarpment are not explained simply by a smaller depth to basement. We also note that over the Outer High (Fig. 1), which has been interpreted as a structural high¹ and where basement (from reflexion profiler data) is known to be buried under less than 2 km of sediments in some areas, there are no large magnetic anomalies (Fig. 2). But large magnetic anomalies exist over some portions of the continental shelf where basement is buried under several kilometres of sediment. Adam³ shows several examples of such anomalies where depths of up to 8 km to basement are estimated. The magnetic anomaly at Frøyabanken (63° 50' N, 7° E) is especially prominent. The anomaly exceeds 1,300 gamma. Depth to basement has been estimated to be about 4 km.

Therefore, we believe that the magnetic quiet zone over

the Norwegian continental margin cannot be attributed to a large thickness of sediments. Rather, the basement rocks possess different magnetic properties. We suggest that continental basement lies landward of the escarpment and oceanic basement lies seaward.

A major change in basement elevation should be expected at the boundary between oceanic and continental crusts. The density of the continental crust must be different from that of the newly formed oceanic crust and, unless densities in the underlying mantle are rearranged in a peculiarly coincidental way, isostasy requires the two kinds of crusts to be balanced with different resultant elevations. Differences in basement elevation are observed for both the Vøring Plateau Escarpment and the Faeroe-Shetland Escarpment but are not reflected in topography due to the deposition of a large thickness of Cainozoic sediments. The steep gradient in the isostatic anomaly profiles at the escarpment (Fig. 2), however, is also indicative of change in basement elevation.

Prominent magnetic and gravity anomaly belts exist on the shelf off Norway (Fig. 1). MS and GS lie at the shelf edge; ML and GL which seem to be similar in nature exist over the Lofoten Islands. Two lines of argument suggest that the rocks giving rise to these anomalies are very old. First, these belts seem to be associated with Pre-Cambrian rocks in the Lofoten Islands as well as at the Laxfordian and Scourian assemblages of northwest Scotland

which are also of Pre-Cambrian age. We have been able to show that belt GS runs into Scotland. Second, the magnetic maximum MS is systematically landward of the gravity maximum GS. If both the gravity and magnetic anomalies are attributed to the same body the angle of inclination of magnetization must be very small¹. Large values of Q would then imply that the direction of remanent magnetization has a small inclination; smaller values of Q would imply a still smaller inclination or a reversed direction of remanent magnetization. These observations do not exclude a Pre-Cambrian age for these belts.

Perhaps the most important question raised by the great age of these belts is the circumstance of their location at the shelf edge. There has been considerable speculation as to the origin of gravity and magnetic highs near the edge of continental shelves, which seem to be associated in general with rocks of different ages⁵. In our view, the gravity and magnetic highs on the Norwegian shelf do not occur as a result of a location near the shelf edge, but rather the location of the shelf edge is predetermined by high density belts extending deep into the crust. The distribution of sediments deposited prior to the opening of the Norwegian Sea indicates that the thickness over these belts has been relatively the smallest. We infer that these belts underwent the least pre-opening subsidence. After the opening these belts have been similarly resistant to subsidence and appear to define a hinge line for the post-opening subsidence of the area between the shelf and the marginal escarpments.

Continental Margin off South Africa

We have also investigated the continental margin off South Africa (Fig. 3). A magnetic quiet zone exists over the shelf and the upper slope. On the southeast side the magnetic quiet zone is bounded by a prominent linear anomaly situated near the base of the slope⁶ (Fig. 4). This magnetic anomaly is associated with a fracture zone (J. Frencheteau and X. LePichon, unpublished), here named the Agulhas Fracture Zone. In Fig. 6 the topographic, gravity (isostatic) and magnetic profiles are shown for the V1810 crossing. We note that the magnetic profile shows no change in character at the shelf edge but near the base of the slope a large anomaly coincides with a large gradient in the isostatic gravity profile. Seaward of this point the magnetic field is much more irregular. Other magnetic profiles which cross the fracture zone from the shelf to the deep sea show similar characteristics. On the other hand, the magnetic profiles crossing the fracture zone where there is deep ocean on either side do not exhibit any noticeable change in pattern (Fig. 4).

Seismic reflexion profiler records (Fig. 3) show that oceanic basement can be followed westward from the basin to the base of the slope. Basement is not seen landwards of the fracture zone. We attribute this to a greatly increased thickness of sediment. Many seismic refraction results have been obtained in the area⁷⁻¹⁰; in Fig. 3 we show three typical profiles. Seaward of the Agulhas Fracture Zone the M discontinuity is found at depths associated with a typical oceanic structure. Landward of the fracture zone depths to M have not been obtained. But for continental shelves generally and this shelf particularly (because of the continuity of land structures beneath the shelf⁸⁻¹⁰) the crust is considered to be continental in nature. The area in which the nature of the crust is in question seems to have been the area between the shelf edge and the fracture zone. But we believe that the absence of any difference in the character of the magnetic anomaly at the shelf edge demonstrates clearly that the boundary between oceanic and continental basement is near the base of the slope rather than at the shelf edge.

Profiles across the continental margin west of Cape Town are shown in Fig. 5. A steep gradient in the isostatic gravity

MAGNETICS

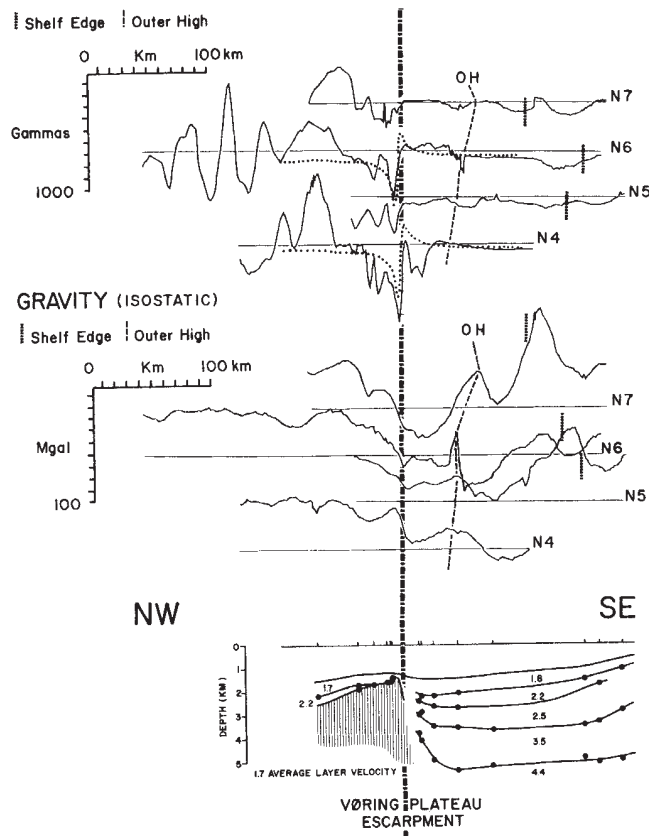


Fig. 2 Profiles of magnetic and isostatic gravity anomalies and a seismic structure section across the Vøring Plateau Escarpment. The location of profiles N4–N7 shown in Fig. 1. The profiles are projected normal to the escarpment. The subdued nature of the magnetic anomalies southeast of the escarpment is quite apparent. In profile N4 the escarpment is not as steep as in other profiles and the magnetic anomaly landward of the escarpment is associated with basement topography. The computed anomaly caused by a semi-infinite horizontal plate 0.5 km thick lying seawards of the escarpment and with its edge coincident with the escarpment is superimposed on magnetic profiles N6 and N4. The top of the plate is at a depth of 1.5 km and it is assumed to be magnetized with an intensity of magnetization 0.012 e.m.u. in a direction opposite to the direction of the present dipole field (which is very close to the direction of the Earth's gravity field in the Early Tertiary). The line OH (also see Fig. 1) which delineates a structural high is determined from the isostatic gravity anomaly and seismic reflexion profiler data. The seismic section is constructed by projecting station positions on a profile normal to the escarpment. The station positions are shown in Fig. 1. Black dots indicate layer boundaries. Average layer velocities are shown. Note that no stations are located on the Outer High which is therefore not reflected in the seismic section.

profile is associated with the initial appearance of the sea-floor spreading type magnetic anomalies. The relative positions of the gravity and magnetic anomalies with respect to the topography are seen best in profile C1314a in Fig. 6. The magnetic high M (Figs. 3 and 5) on the slope has been followed northwest to 31° N (ref. 12).

Comparison of the Two Margins

Comparing the Norwegian margin to the South African margin, the Agulhas Fracture Zone corresponds to the Jan Mayen Fracture Zone, and the seaward edge of the magnetic quiet zone west of Cape Town appears to correspond to the marginal escarpment off Norway.

We have made model calculations to match the magnetic anomalies at the Vøring Plateau Escarpment, the marginal

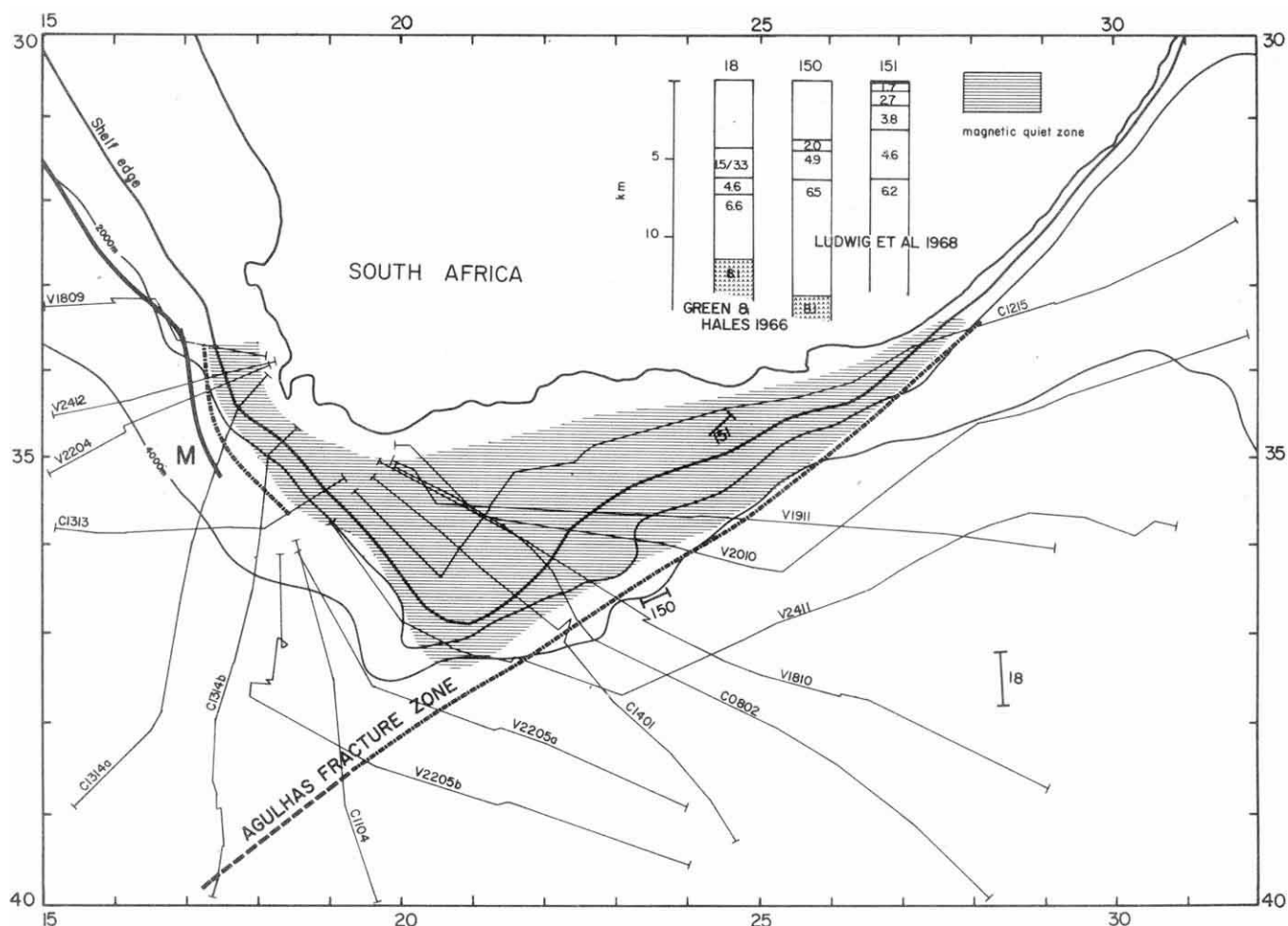


Fig. 3 Prominent gravity and magnetic features of the South African continental margin. The Agulhas Fracture Zone near the base of the continental slope is coincident with a steep gradient in the isostatic gravity anomaly and a peak in the magnetic total intensity anomaly. A similar line on the western margin on the continental slope is also associated with a steep gradient in the isostatic gravity anomaly. A peak in an associated magnetic anomaly, M, lies some distance seaward and is continued further north from the data of Simpson and duPlessis¹¹. Seismic refraction profile 151 (ref. 8) is typical of a number of profiles located on the shelf; profiles 150 and 18 (refs. 7, 8) are representative of oceanic crustal structure.

anomalies west of Cape Town and at the Agulhas Fracture Zone.

Northwest of the Vøring Plateau Escarpment the seafloor spreading type basement is associated with reversely and normally magnetized stripes parallel to the escarpment. We have calculated the anomaly corresponding to the edge of a reversely magnetized plate (Fig. 2). The prominent negative anomaly at the escarpment is reproduced by this model. Westward the observed anomalies fluctuate about the level of the model anomaly, which is not unexpected because we did not consider the changes of polarity in the adjacent stripes. A similar calculation for the edge of a normally magnetized plate is made to match the slope anomaly west of Cape Town (Fig. 6). If our models are correct, we deduce that the opening of the Norwegian Sea took place in a period of reversed polarity while the South Atlantic opened in a period of normal polarity. Off the Agulhas Fracture Zone the magnetic stripes are presumably perpendicular to the fracture zone; but we believe that the fracture zone is characterized by a zone of ultramafic rocks for which the magnetization is primarily induced, and we have computed the anomaly caused by the edge of a plate magnetized by induction in the Earth's present field. The fit of the model to the observed anomaly is quite good (Fig. 6).

We have observed a large gradient in the isostatic gravity anomalies at the suggested boundary between continental

and oceanic basement. In part, at least, this gradient reflects the thicker section of sediments on the landward side of the boundary. In any event, the gravity low between this boundary and the shelf edge appears to be diagnostic of the subsided continental crust and could be of great use in examining other continental margins. We have used isostatic anomalies rather than free air anomalies. Free air anomalies at continental margins exhibit "edge effects" which arise from the difference in the gravitational effects of topography and its compensation. These edge effects tend to mask anomalies caused by local density inhomogeneities which are much better revealed by isostatic anomalies. Of course, isostatic anomalies are subject to error because of lack of knowledge of the completeness and mode of compensation. For stable margins, however, even a considerable variation in isostatic model causes only minor changes in the isostatic anomalies and therefore even though the model may be wrong in detail the isostatic anomalies provide very useful information. Both on the western and the southeastern margin off South Africa free-air highs on the shelf edge are considerably reduced and the anomalies on the slope are enhanced when the isostatic reduction is made.

There is considerable uncertainty as to the detailed crustal structure of most continental slopes. The area of the slope is generally quite close to isostatic equilibrium but seismic refraction stations¹² do not reveal the simple Airy com-

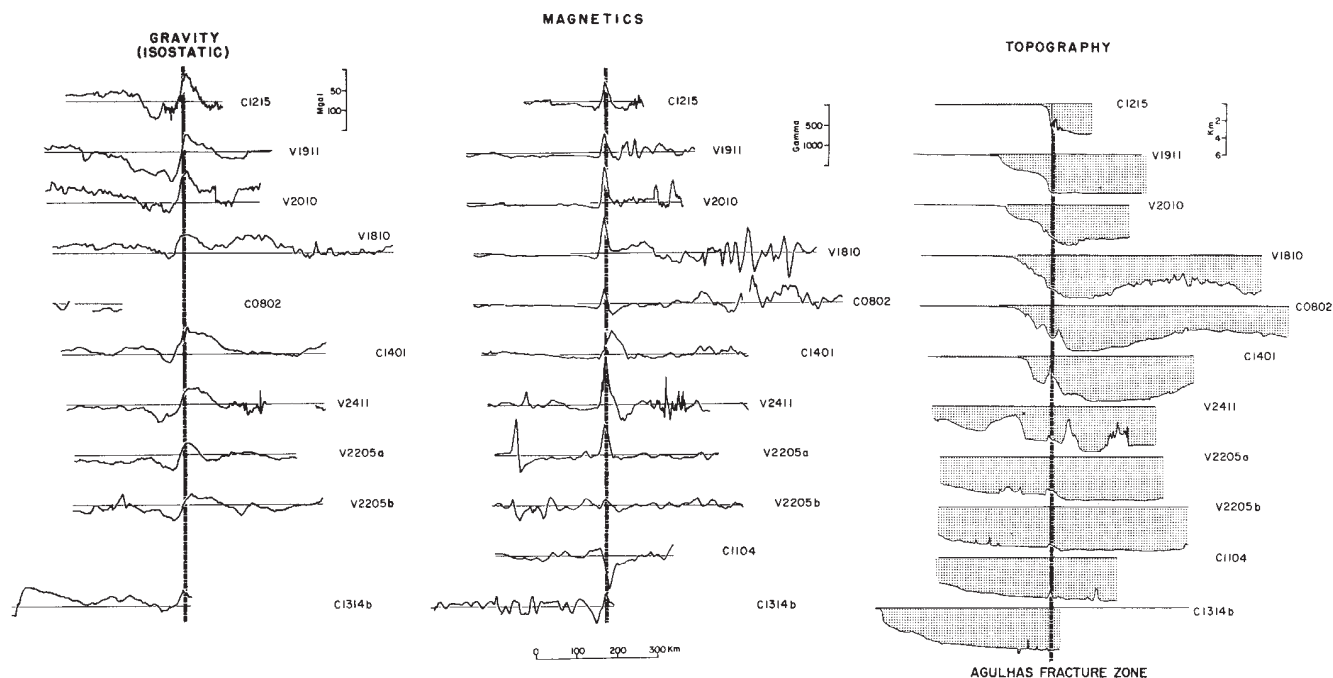


Fig. 4 Projected profiles of isostatic gravity anomalies, magnetic anomalies and topography across the Agulhas Fracture Zone (for locations see Fig. 3). North of profile V2411 the Agulhas Fracture Zone lies between the shelf and the deep ocean; south of profile V2205a it has deep ocean on either side. There is a steep gradient in the isostatic gravity anomaly associated with the fracture zone. This gradient is especially prominent in the northern profiles, as is a large magnetic positive anomaly.

pensation scheme implied by a smooth change in depth to the mantle from ocean to continent on most stable continental margins. As a general rule the velocities for both layer 3 and the mantle are lower under the slope and show much more variability than they do under the normal ocean. If the continental slope indeed represents subsided continental crust, an exact determination of the seismic structure would give an indication on how isostatic compensation is achieved for subsided margins. A comparison of seismic velocities between subsided and unsubsidied areas could also give important information as to the nature of rocks comprising the crust.

The boundary discussed above has obvious implications

for the reconstruction of rifted continents in that it represents the line of initial rifting. We do not, however, intend to imply that there has been no deformation in what we have called the subsided continental zone. It is unlikely that the continents rifted with a clean break at this boundary. Rather, as widely suggested, the extrusion of oceanic crust was probably preceded by a period of stretching and thinning of the continental crust achieved in part by normal faulting. Therefore, in the subsided zone it is perhaps more correct to speak of a continental basement over a modified crust rather than to imagine an undeformed continental crust. Strictly speaking, a complete reconstruction would not be made just to this boundary, but would

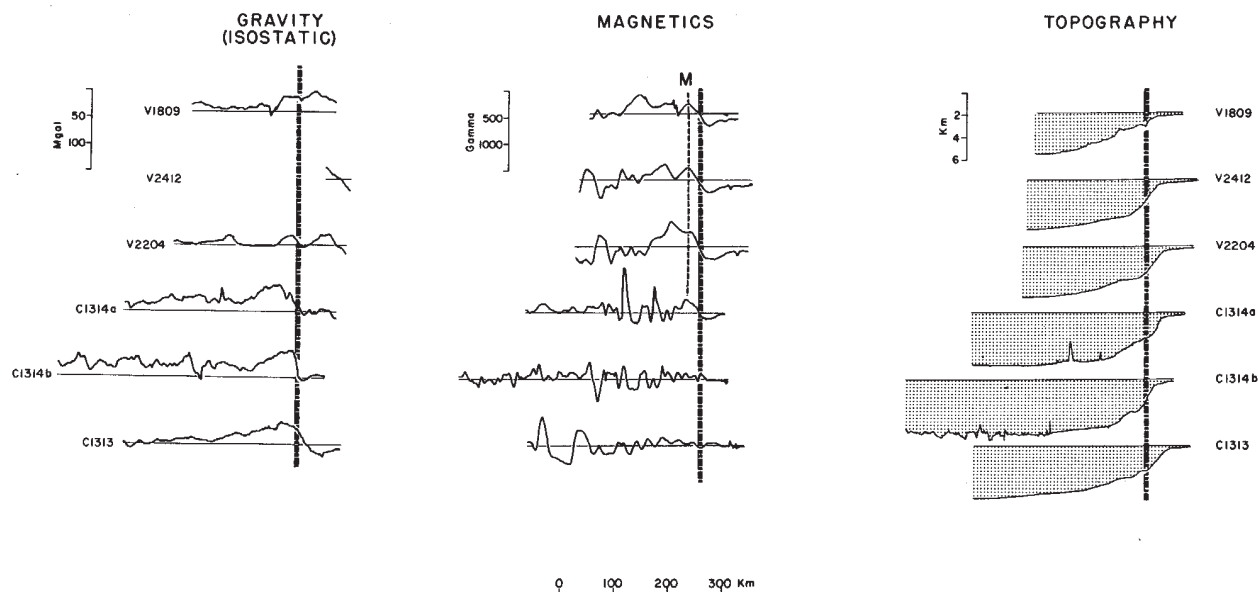


Fig. 5 Projected profiles of isostatic gravity anomalies, magnetic anomalies and topography across the western margin off South Africa. The reference line marks a steep gradient of the isostatic gravity anomalies. The magnetic maximum M lies further west.

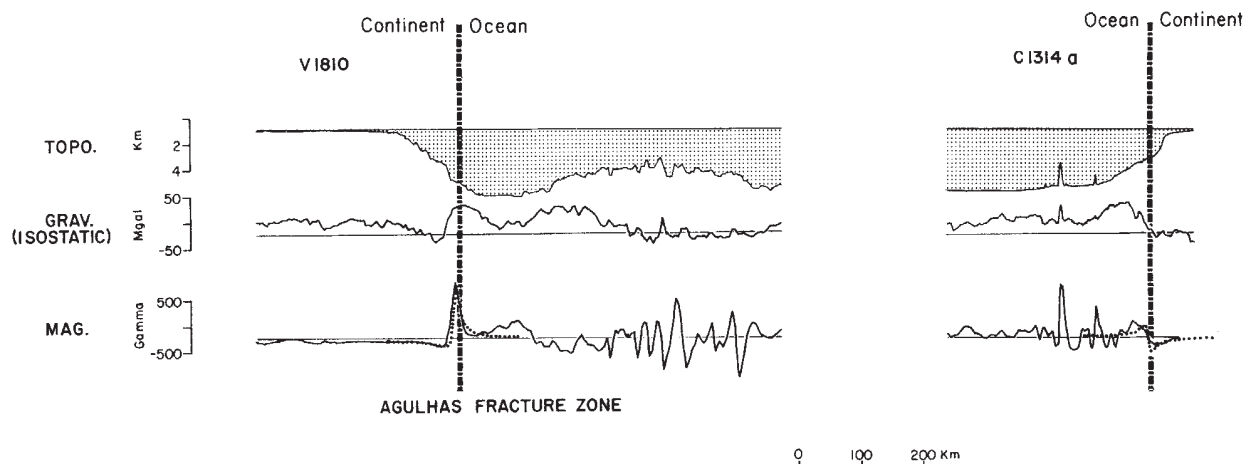


Fig. 6 Left: topography, isostatic gravity and magnetic anomaly profiles V1810. Note that the shelf break is not reflected in the magnetic anomaly and that isostatic gravity profile has a low in the area between the shelf break and the Agulhas Fracture Zone. The dotted curve is the computed anomaly caused by a semi-infinite horizontal plate 2 km thick lying seaward of the fracture zone and with its edge coincident with the fracture zone. The top of the plate is at a depth of 4 km and it is assumed to be magnetized by induction with a susceptibility of 0.04 cgs units. Right: topography, isostatic gravity and magnetic anomaly profiles C1314a. The dotted curve is the computed anomaly caused by a semi-infinite horizontal plate 1 km thick lying seaward of the reference line in Fig. 5. The top part of the plate is at a depth of 4 km magnetized in a field with declination 322.5° and inclination -62° . These are directions of the Earth's magnetic field in the Late Jurassic in South Africa⁴. Intensity of magnetization is 0.012 e.m.u.

in addition have to allow for the stretching of the continental crust.

Other Margins

In applying our thesis to other areas two qualifications are necessary. The first derives from the nature of continental basement, which is not always characterized by a lack of magnetic anomalies. Second, some magnetic quiet zones in oceanic areas are attributed to a lack of magnetic reversals^{10,14-16}. The seaward portion of the magnetic quiet zone in the western North Atlantic has been attributed to an interval of constant magnetic polarity^{13,16,17}. This does not rule out the possibility that the inner (landward) portion of the western North Atlantic quiet zone is also a marginal quiet zone of the type discussed here. In fact, within the western North Atlantic quiet zone a prominent magnetic lineation called the Blake-Spur anomaly^{14,18} trends northeastwards from 30° N, 76° W. The magnetic pattern is considerably more subdued in the area landward of this anomaly (which may represent subsided continental crust) than seaward which represents an oceanic quiet zone due to an interval of constant magnetic polarity in the Jurassic¹⁷.

A prominent escarpment near the base of the slope exists off the coast of West Africa between 13° S and 5° S (ref. 19) which possibly marks the boundary of continental and oceanic crust. Further north Arens *et al.*²⁰ have mapped the "continental rise fault" between the St Paul and Romanche fracture zones in the Gulf of Guinea. The basement is several km deeper on the landward side of this fault. The "continental rise fault" may mark the boundary of continental and oceanic basements. The possibility also exists that the deep sedimentary basin lying between Fuerteventura in the Canaries and Africa²¹ is also underlain by continental basement. We consider this possibility because the oldest sediments in this basin are believed to be Upper Palaeozoic (and therefore deposited before the initiation of the North Atlantic opening) and because the area is magnetically quiet except for the presence of a single anomaly which trends obliquely across the bathymetry on to the shelf. It is of some interest to speculate that the marginal magnetic quiet zones south of Australia and north of Antarctica²³ also represent subsided continental crust.

We feel that it is important to establish the presence of the boundary between oceanic and continental basements

at various rifted continental margins. As outlined here, this boundary is characterized by a contrast in depth and age of basement and the nature of magnetic anomalies on either side as well as by the presence of negative isostatic anomalies on the landward side.

The data used in this study were collected and analysed as part of marine geophysical programmes supported by the Office of Naval Research and the National Science Foundation. We thank E. M. Herron and W. C. Pitman III for comments. John Ewing and W. J. Ludwig critically reviewed the manuscript.

Received July 19, 1972.

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LETTERS TO NATURE

PHYSICAL SCIENCES

Record-breaking Cosmic Ray Storm stemming from Solar Activity in August 1972

AN unusual centre of solar activity was the seat of the most severe disturbances of the current solar cycle early in August 1972. It produced reports from the general public of various visual phenomena in the night sky, surges in electrical systems, radio blackouts and effects upon the navigation of birds in flight. Of the great variety of physical phenomena associated with this remarkable region (sunspot group 331, McMath plage region 11976, centred at Carrington, longitude 009 degrees), we will concentrate on a description of the gross features of the greatest cosmic ray storm ever observed that commenced on August 4, and of which sunspot group 331 was the ultimate source.

A cosmic ray storm comprises a superposition of Forbush decreases, that is, a series of sudden reductions in the intensity of the galactic cosmic radiation¹. Although cosmic rays have been recorded continuously with ground-based detectors for almost four decades¹, only one event of comparable magnitude had been observed previously. That was in July 1959, during the epoch when solar activity was greater than at any time since Galileo first observed sunspots in 1610 (ref. 2). In that case, the nucleonic intensity at a polar station was reduced to 24% below the pre-storm level seven days and three Forbush decreases after onset¹. But the cosmic ray storm of August 1972 occurred near the minimum of an unspectacular solar

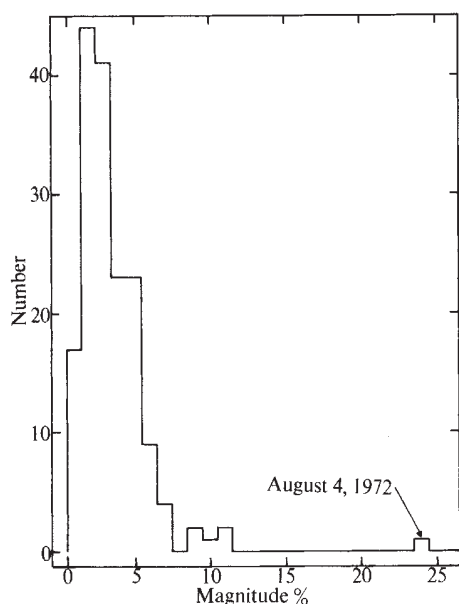


Fig. 1 Histogram showing the size distribution of transient nucleonic intensity reductions, as observed at a station with directions of viewing near the equatorial plane, and for which the lower energy threshold is close to the atmospheric cutoff. All significant cosmic ray storms or individual Forbush decreases that occurred during an eleven-year period (July 1961–August 1972) corresponding to the duration of a complete sunspot cycle are included. As the frequency of occurrence and average magnitude is greater near solar maximum⁸, the storm commencing on August 4, 1972, during the waning portion of the current solar cycle, is clearly anomalous.

cycle, and the magnitude of the decrease reached 27% in about twenty-four hours.

The unusual character of this event is further revealed in Fig. 1, which shows the distribution in the size of cosmic ray storms as observed with a detector viewing the equatorial plane to minimize the effects of north–south anisotropies in the modulation. From July 1961 to August 1972, corresponding to the period of one solar cycle, more than 90% of the intensity decreases were $\leq 6\%$, and the maximum flux reduction was only half as great as it was in the present case.

Region 331 was born on the visible disk of the Sun near N 13° W 36° on July 11, 1972. Its first passage, terminating on the west limb on July 15, did not presage the great burst of activity that followed its return to the east limb on July 29. The maximum area of the spot group, about 1,200 millionths of the hemisphere, and extending over about 17 degrees in longitude, was attained on August 4. The region appeared as a single large penumbra containing an intense magnetically complex umbral structure and several distinguishing characteristics.

The cosmic ray storm that commenced at 0130 UT on August 4 is shown in Fig. 2, which is a plot of the time variation of nucleonic intensity as recorded at a mid-latitude station for which the asymptotic directions of viewing lie near the equatorial plane, and the geomagnetic threshold rigidity (1.9 GV) is close to the atmospheric cutoff. It followed three large solar flares that were observed optically (H_α) to commence on August 2 at 0316 UT (Importance 1B, N 14° E 35°), 1838 UT (1B, N 13° E 28°) and 2005 UT (2B, N 13° E 28°). These flares produced the most severe disturbances during the current solar cycle in the many diverse phenomena that are included within the domain of solar-terrestrial physics.

The ledge that appears in Fig. 1 during the onset stage of the initial Forbush decrease FD-1 will be discussed later in the light of observations at other stations in the Bartol neutron monitor network. It terminated at about 2130 UT, when the intensity dropped abruptly to the minimum FD-2, at a rate exceeding 5% per hour during some intervals. While the galactic cosmic ray flux was recovering, an Importance 3B flare that started at 1500 UT (N 14° W 38°) on August 7 produced a ground level event (GLE) representing the arrival of relativistic solar protons beginning at about 1530 UT. This apparently "typical" GLE was followed by a small Forbush decrease FD-3, after which the galactic intensity gradually returned to the predecrease storm level.

Data recorded at polar stations for which the symptomatic directions of viewing lie outside the equatorial plane³ not only provide further insight into the characteristics of this cosmic ray storm, but are also relevant in interpretations of the observations of the majority of stations in the world-wide neutron monitor network which are located at lower latitudes⁴. Fig. 3 shows the intensity profiles at Thule (Greenland) and McMurdo and South Pole (Antarctica).

An anisotropy in the direction perpendicular to the ecliptic plane is a characteristic feature of cosmic ray storms⁵, and produces a north–south asymmetry which manifests itself in systematic differences in the magnitude of a Forbush decrease and/or in the onset times in the two polar regions. A precise determination of the time of commencement of FD-1 in Fig. 3 reveals that it occurred about 2 h earlier at Thule. Presumably as a consequence of this delay, the magnitude of FD-1 at Thule was larger during the first six hours. On the other hand, although the onset of FD-2 at the northern station also preceded the start of this phase of the storm in Antarctica, the extent of the decrease at McMurdo was greater for several hours. At 0130 UT on August 5 the magnitudes of the intensity

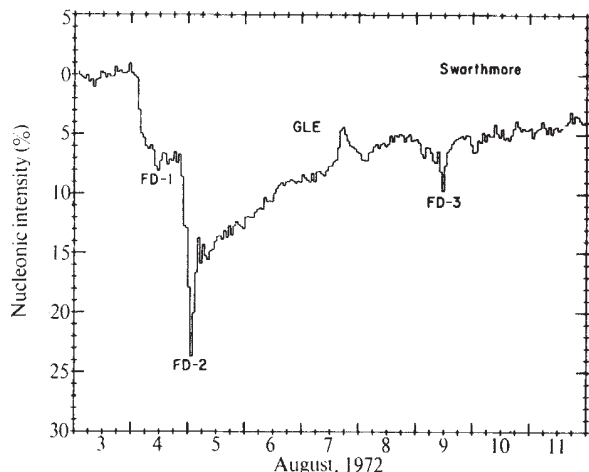


Fig. 2 Nucleonic intensity profile of the record-breaking cosmic ray storm as observed at a typical mid-latitude station (see Fig. 1).

reductions at the four stations were: Thule, 21.5%; Swarthmore, 23.7%; McMurdo, 26.8%; and South Pole, 35.2%.

The differences among the first three, all located near sea level, are a consequence of north-south anisotropy, whereas the predominant factor causing the enhancement of the effect at South Pole is the high altitude at which that station is located.

The most striking feature of Fig. 3 is the transformation of the ledge in Fig. 1 into an intensity increase GLE-1 at the polar stations. A feature of this appearance could represent either (a) a discontinuity in the modulation mechanism, arising from the anisotropic nature of solar plasma⁶, or (b) the arrival of relativistic solar cosmic rays (GLE). We now examine these two possibilities, and cite the evidence leading to the tentative identification of this structure in the intensity profile as the second alternative.

The following mechanisms have been invoked in the past to account for transient intensity increases during Forbush decreases:

(1) Transient longitudinal anisotropy⁷. This effect is related to an asymmetric longitudinal distribution of the solar plasma responsible for the modulation. This mechanism would produce a phase difference between Thule and McMurdo of about eight hours, contrary to the observations (Fig. 3).

(2) Reduction in threshold rigidity⁸. The atmospheric rather than geomagnetic cutoff determines the energy threshold at the polar regions, hence an intensity increase at these stations cannot be produced by a reduction in geomagnetic threshold rigidity.

(3) Worldwide modulation. An abrupt discontinuity caused by a new shock wave overtaking a predecessor, or some other disturbance in the interplanetary medium, might produce an increase by opening a window to the outside galactic flux. At first glance, this mechanism seems attractive, as the GLE-1 maxima at both Thule and McMurdo just reached the pre-Forbush decrease level (Fig. 3). But the time resolution afforded by the recordings in two-minute intervals made it possible to determine that, for at least fourteen minutes, the cosmic ray flux significantly exceeded the pre-storm level at Thule. Furthermore, the intensity increase recorded by the South Pole nucleonic detector, which has a lower atmospheric cutoff, appreciably exceeded the pre-storm level for three hours.

These observations suggest that GLE-1 represents the arrival at the Earth of relativistic particles of solar origin. The most likely candidate for the source is an Importance 2B flare (N 15° E 09° that started on 0621 UT and ended at 0852 UT on August 4). The only dilemma with this association relates to the apparently longer than normal delay in the onset of this GLE. But the complexity introduced by the superposition of the arrival of solar particles and the modulation of the intensity of galactic cosmic rays precludes a precise determination of the onset time of GLE-1.

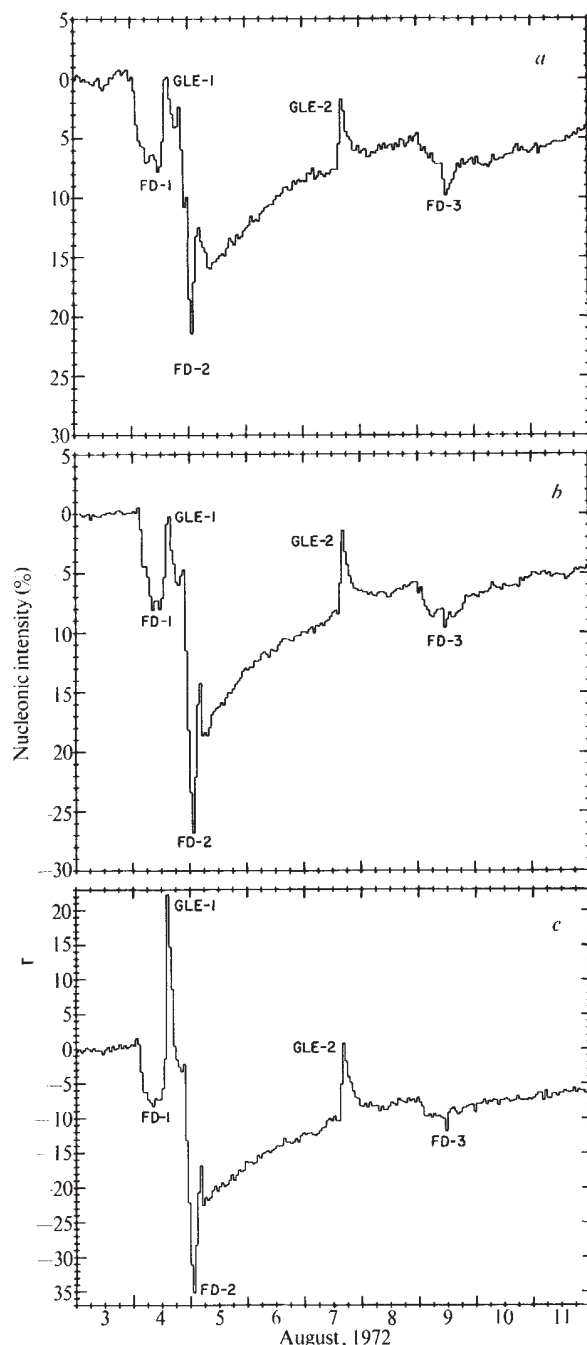


Fig. 3 Observations at the polar stations. Thule, Greenland (a), and McMurdo, Antarctica (b), are near sea level and view directions of arrival that are essentially perpendicular to the ecliptic plane. South Pole (c) is at an atmospheric depth of 680 g cm⁻², and its asymptotic cone lies at a somewhat lower latitude³.

It is interesting to note that these observations of this great cosmic ray storm, which occurred near an epoch of minimal intensity modulation, imply that the primary cosmic ray flux in the vicinity of the Earth was cut almost in half by disturbances in a single localized region on the Sun.

This work was supported by the National Science Foundation and by the Air Force Cambridge Research Laboratories, Air Force Systems Command.

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Received October 2, 1972.

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Solar Gamma Ray Lines observed during the Solar Activity of August 2 to August 11, 1972

WE report preliminary observations from OSO-7 on the emission of gamma ray lines associated with the solar flares on August 4 and 7, 1972. This is the first observation of such solar gamma rays.

The gamma ray monitor¹ consists of a shielded 3 inch by 3 inch NaI(Tl) crystal located in the rotating wheel compartment of OSO-7. Two pulse height spectra are accumulated simultaneously in the solar and background quadrants (Fig. 1) over ~90 wheel rotations in a 377-channel quadratic² pulse height analyser with a time resolution of 3 min. At each day/night or night/day transition of the satellite, a ⁶⁰Co spectrum is electronically gated into the pulse height analyser³. The results presented here are based on analysis of preliminary data tapes.

The 2B H_α flare of August 4, 1972, began at ~0621 UT, reaching a maximum at 0638 UT and ending at ~0852 UT (Preliminary Report SESC-PRF-Boulder 092,093). Before the satellite went into eclipse at ~0633 UT, excess gamma ray line and continuum radiation was observed. Figs 2 and 3 show a sequence of counting rate spectra which were taken before the commencement of the optical flare, during the rise of the optical flare and just after the commencement of satellite night. The live times of the summed spectra shown range from ~80–100 s. Fig. 2 shows the spectral range from ~435 to 615 keV, and Fig. 3 from ~2.1 to 2.4 MeV for accumulation in the time intervals shown. Reference to the central spectrum pairs indicates that only the solar quadrant gamma ray flux is significantly enhanced in both the ~0.5 and ~2.2 MeV

spectral regions during the rise time of the optical flare. In addition, the general continuum below the line features is enhanced over the background quadrant, indicating a continuum enhancement to above 2 MeV.

A more detailed spectrum shows evidence for solar flare gamma ray line structure centred at several different energies but especially at ~4.4 and ~6.1 MeV.

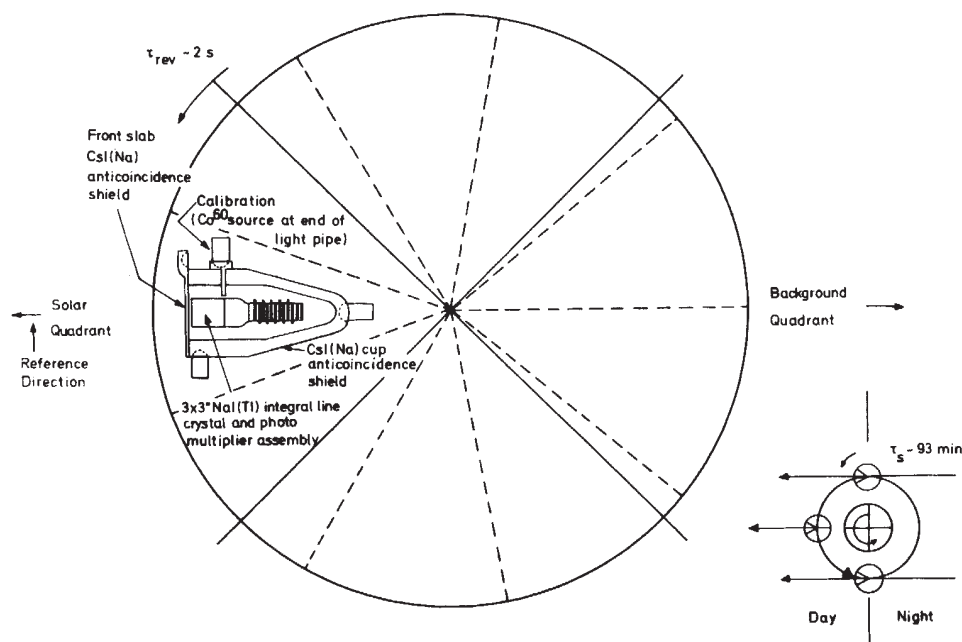
Fig. 4 shows the counting rate versus time in an X-ray band (60–120 keV) and for the gamma ray lines centred at 0.5 and 2.2 MeV. The X-ray data, taken from the 4-channel X-ray detector associated with the gamma ray monitor⁴, show the beginning of an increase near the time of the commencement of the reported optical flare reaching a maximum in about 5 min. The spectral features at 0.5 and 2.2 MeV begin to increase at about the same time as in the X-ray channel but with a slower rise.

The most straightforward interpretation of these observations is the near simultaneous production of nonthermal X-rays to energies greater than 2 MeV and gamma ray lines produced by a variety of high energy reactions associated with the production of solar cosmic rays. The most likely sources of the gamma ray lines are positron (β^+) production followed by annihilation (0.51 MeV), production of neutrons by solar cosmic rays followed by capture in solar hydrogen (2.22 MeV), and inelastic proton scattering^{4,5}. Calculations by Shima and Alsmiller⁶ and comparisons with experiments at Oak Ridge show that the gamma ray spectra produced by protons on light elements such as C and O are considerably more complex than assumed in the earlier calculations^{4,5}. Thus one must be quite careful in deciding just which processes are predominant in producing the spectral features we see. We note that there may be a delay in the rise time of the enhancements shown in Fig. 4 because of the slowing down and capture times for the positrons and neutrons.

Additional evidence for the lines at 0.5 and 2.2 MeV was obtained during the 3B flare of August 7, 1972. The 3B flare began in H_α at ~1500 UT during satellite night-time. As the satellite emerged into the sunlight, excess gamma ray line radiation was observed. Figs. 5 and 6 show a sequence of counting rate spectra which were taken at night-time and during the satellite daytime period while the 3B H_α flare was still in progress.

Fig. 5 shows the spectral range from ~435 to 610 keV, and Fig. 6 from ~2.0 to 2.4 MeV for accumulations in the time intervals shown. Comparison of the lowest spectrum (night-time) with that immediately above it (daytime) shows that there are statistically significant increases in the two spectra

Fig. 1 Schematic drawing of the gamma ray spectrometer, shown with the OSO wheel in the position for viewing the Sun. The solar and background quadrant identifications are also shown. The small inset at the right shows satellite aspect at sunrise and at noon and at sunset.



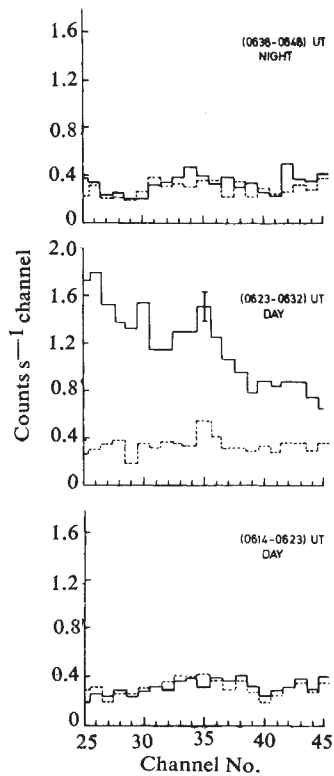


Fig. 2 The gamma ray pulse height spectrum is shown for the energy region 435 keV-615 keV on August 4, 1972. The lower spectrum was taken in the daytime before the start of the 2B H_{α} flare and the central spectrum was taken during the rise of the optical flare. The spectrum at the top was taken just as the satellite was occultated by the Earth. The accumulation time intervals are shown for each spectrum. —, Solar quadrant; ---, background quadrant.

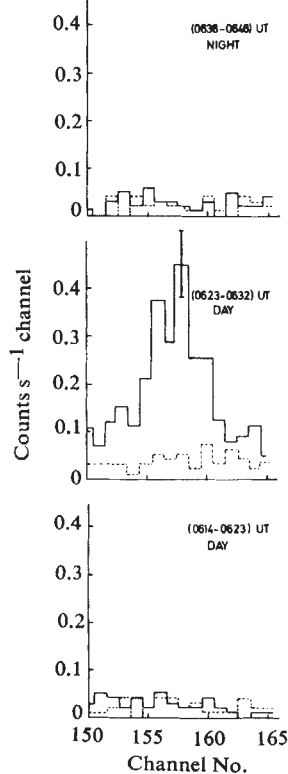


Fig. 3 The gamma ray pulse height spectrum is shown for the energy region 2.1 MeV-2.4 MeV on August 4, 1972. The lower spectrum was taken in the daytime before the start of the 2B H_{α} flare and the central spectrum was taken during the rise of the optical flare. The spectrum at the top was taken just as the satellite was occultated by the Earth. The accumulation time intervals are shown for each spectrum. —, Solar quadrant; ---, background quadrant.

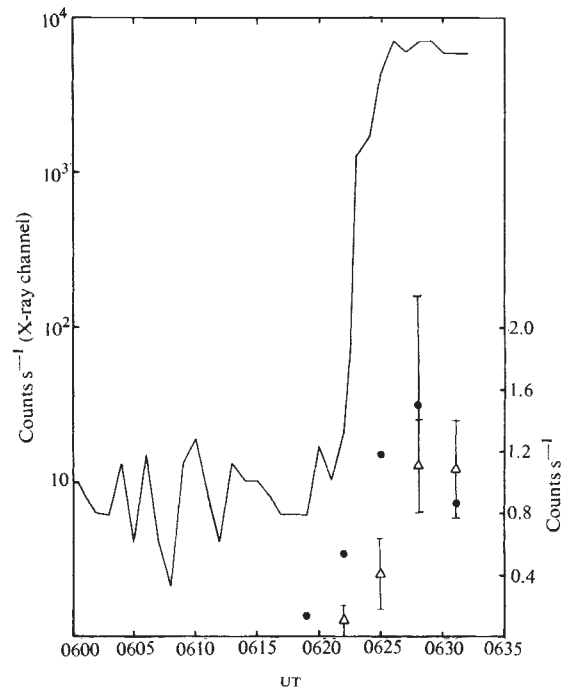


Fig. 4 The time profile (—) for the counting rate in one X-ray channel (60-120 keV) is shown covering the period of satellite day from about 20 min before the optical onset until the satellite went into eclipse. Also shown are the time profiles for the counting rates in the five channels corresponding to gamma ray lines at 0.5 MeV (●) and 2.2 MeV (△).

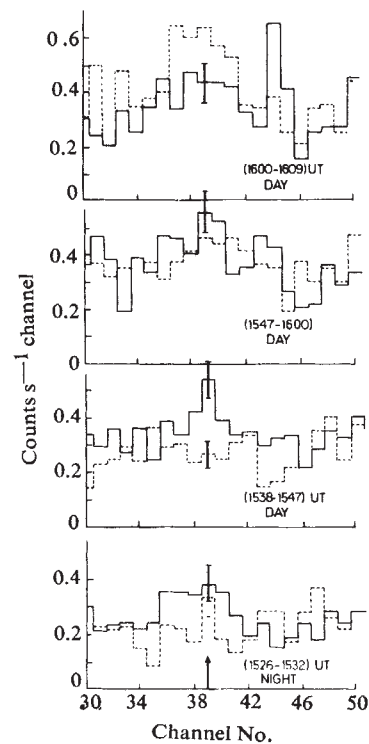


Fig. 5 The gamma ray pulse height spectrum is shown for the energy region 435 keV-610 keV on August 7, 1972. The lower spectrum was taken at night-time just before the satellite sunrise, but while the 3B optical flare was in progress. The second spectrum from the bottom was taken just after the sunrise calibration and during the declining phase of the optical flare. The top two spectra were taken at later times in the same orbit during the satellite daytime. The accumulation time intervals are shown for each spectrum. —, Solar quadrant; ---, background quadrant.

Table 1 Tentative Designations and Preliminary Solar Flux at 1 a.u. (photons cm⁻² s⁻¹)

Associated flare and time of observations	0.5 MeV	2.2 MeV	4.4 MeV	6.1 MeV
2B (H _α) August 4, 1972, 0623–0632 UT (before H _α max)	$(7 \pm 1.5) \times 10^{-2}$	$(2.2 \pm 0.2) \times 10^{-1}$	$(3 \pm 1) \times 10^{-2}$	$(3 \pm 1) \times 10^{-2}$
3B (H _α) August 7, 1972, 1538–1547 UT (after H _α max)	$(3.7 \pm 0.9) \times 10^{-2}$	$(2.6 \pm 1) \times 10^{-2}$	$< 2 \times 10^{-2}$	$< 2 \times 10^{-2}$

corresponding to photon energies of 0.5 and 2.2 MeV respectively. In both figures the enhancement appears only in the solar quadrant spectra just after sunrise. We suggest that the enhancements here are also due to a direct solar flux, because we expect that a local satellite or atmospheric effect would produce an enhancement in both the solar and background quadrants for the detector's aspect with respect to Earth just after the night-to-day transition. The upper spectrum in Fig. 5 shows an increase in the 0.5 MeV region in the background quadrant. At this time this quadrant was viewing the Earth with good aspect but a lower rigidity ~ 8.0 GV, and therefore registered atmospheric radiation.

We conclude therefore that the monitor has recorded a solar burst most probably of annihilation radiation (0.51 MeV) and the deuteron formation gamma ray (2.22 MeV) in the flares on August 4 and August 7, 1972. In addition, there were solar gamma ray lines emitted during the 2B flare on August 4, 1972, most probably from excited states of ¹²C and ¹⁶O. Table 1 gives a brief summary of tentative solar flux values at the Earth for the spectral lines mentioned above in the case of both flares. For the 3B flare conservative upper limits are given for the C and O lines for the same time period.

The latter gamma ray lines are all from short-lived, excited nuclear states of the indicated nuclides and do not represent all the lines expected, but these have received considerable theoretical consideration^{4,5,7}.

The present observations of solar gamma ray lines are incomplete because the satellite was occulted by the Earth during the maximum of H_α emission in both flares. The

observations presented here cannot eliminate the possibility that gamma rays and neutrons are produced at an undetectable level before the start of the optical flare⁸. It is tempting though to believe that these two observations in themselves give direct evidence that solar cosmic rays are accelerated in the explosive phase of the optical flare^{9,10}.

This work has been supported by NASA contracts. One of us (E. L. C.) acknowledges Alexander von Humboldt and Fulbright fellowships.

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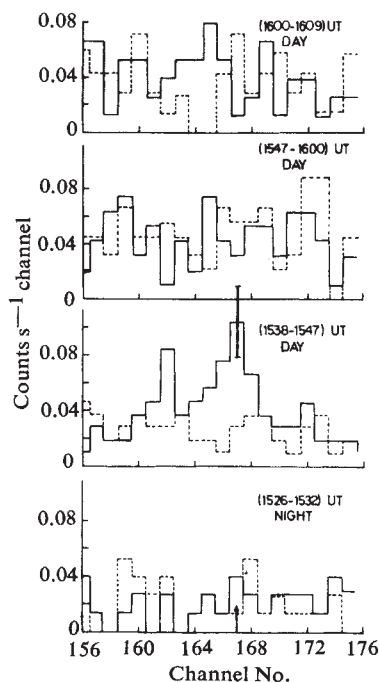


Fig. 6 The gamma ray pulse height spectrum is shown for the energy region 2.1 MeV–2.4 MeV on August 7, 1972. The lower spectrum was taken at night-time just before the satellite sunrise but while the 3B optical flare was in progress. The second spectrum from the bottom was taken just after the sunrise calibration and during the declining phase of the optical flare. The top two spectra were taken at later times in the same orbit during the satellite daytime. The accumulation time intervals are shown for each spectrum. —, Solar quadrant; ----, background quadrant.

Detection of Relativistic Solar Particles before the H_α Maximum of a Solar Flare

WE report here the first direct detection of relativistic solar protons before the H_α maximum phase of a solar flare and in near coincidence with the maximum phase of the white-light flare. These observations have important implications for theories of particle acceleration during flares and for the appropriate particle injection times to be used in the modelling of solar particle events by diffusion theories.

The time development of solar flares is frequently divided into three stages^{1–5}. First, the initial phase, corresponding to local brightenings of H_α and the gradual rise of microwave radio emission and X-ray emission; second, the explosive phase, or flash phase, corresponding to a rapid increase to a maximum in the brightness and area of the flare and a rapid rise to a maximum in the width and brightness of the hydrogen H_α line; third, the decay phase, corresponding to a gradual decay of all of the flare phenomena.

Seventeen ground level solar particle events (GLE) have been observed with neutron monitors between February 23, 1956, and September 1, 1971. In the case of all the GLEs that could be associated with a flare on the visible disk, relativistic particles were first observed at the Earth (1 a.u.) with time delays ranging from ≥ 5 min to more than 1 h following the flare maximum⁴. It has been suggested that

the measured radio and X-ray emissions indicate the presence of relativistic particles at the flare maximum. There have, until now, been no observations of relativistic particles at the Earth prior to, or at the same time as, the flare maximum. This has been interpreted as caused by problems of coronal and interplanetary propagation.

The ground level solar particle event of August 7, 1972, we discuss here was produced by a 3B flare in the McMath region 11976. The location of the flare was reported by the various flare patrol stations to be between W 35° and W 39°. Region 11976 was quite active as it rotated into view on the solar east hemisphere on July 30. A series of flares beginning on August 2, where the region was at ~E 30°, produced large PCA and magnetic storm effects on Earth⁶. Several smaller (1N) flares were observed in region 11976 on August 7 before the 3B flare.

A time history of the pressure corrected galactic cosmic ray rates recorded in Superneutron monitors at Sulphur Mountain (115.6° W, 51.2° N; altitude 2,283 m; vertical threshold rigidity $P_T = 1.14$ GV) and Calgary (114.1° W, 51.1° N, altitude 1,128 m; $P_T = 1.09$ GV) from August 1 to August 13, 1972, are shown in Fig. 1. The values of the solar wind speed recorded at various times by Pioneer 9 (ref. 6) are plotted at the bottom of Fig. 1. During this time Pioneer 9 was at ~0.78 a.u. and 52° east of the Earth-Sun line.

The flares of August 2 produced three shocks reported at Pioneer 9. The latter two of these shocks were observed at Earth at approximately the same time as they were observed at Pioneer 9. The first shock observed at Earth on August 4 produced a Forbush decrease beginning at ~0400 UT. A very large Forbush decrease, amounting to a galactic cosmic ray counting rate decrease of ~28% at maximum, was observed at Calgary and Sulphur Mountain on August 5. The GLE

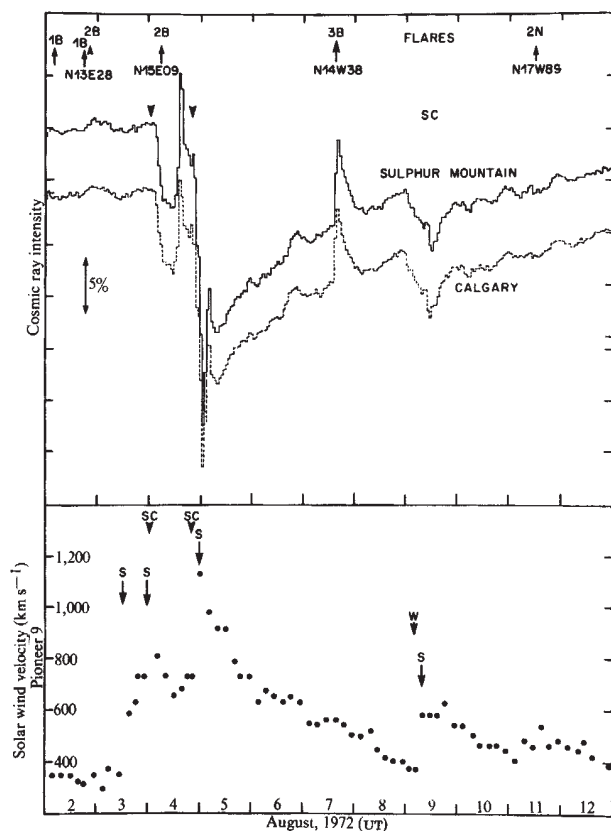


Fig. 1 Superneutron monitor cosmic ray counting rates recorded at Sulphur Mountain and Calgary for the period August 1 to August 13, 1972. Values of the solar wind speed recorded by Pioneer 9 (ref. 6) plotted at bottom. S, Shock at Pioneer 9; W, storm onset (Weston Observatory); SC, sudden commencement.

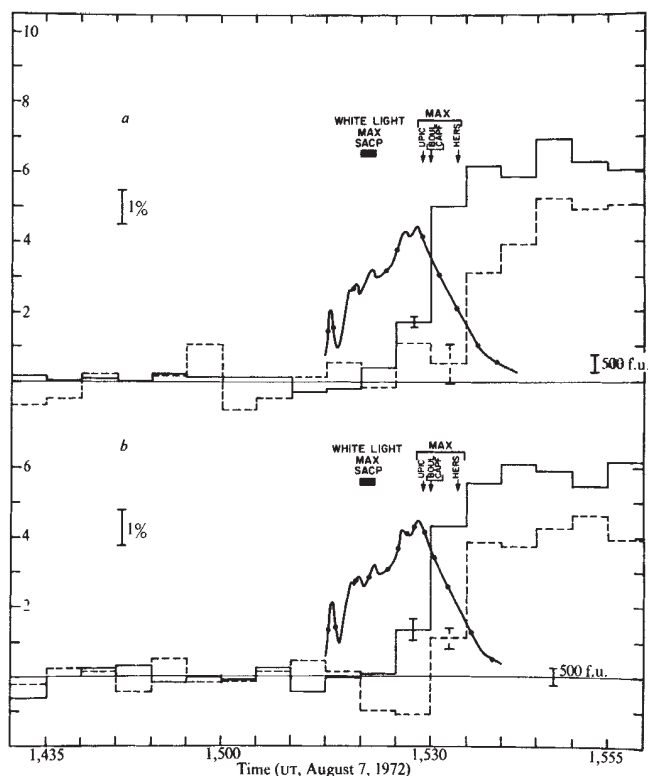


Fig. 2 5-min average cosmic ray counting rates recorded at Calgary, Sulphur Mountain, Deep River and Goose Bay in the period 1430–1600 UT on August 7. The pre-event background counting rate has been removed by subtracting a seven-point sliding average from the data. a: —, Calgary; ---, Goose Bay. b: —, Sulphur Mountain; ---, Deep River. ●—●, 2.8 GHz radio burst data from Ottawa.

event of August 7 occurred during the recovery phase of this large Forbush decrease while the solar wind speed was slowly decreasing from the large values it was observed to have on August 4–5 (Fig. 1). A shock from the August 7 flare was reported at Pioneer 9 on August 9; at about the same time, magnetic storm activity was observed to begin on Earth, although no sudden commencement was reported⁶.

We have examined the onsets of the solar particle events in the neutron monitors at Sulphur Mountain and Calgary on a time scale of 5-min average counting rates. First, the pressure corrected rates from both stations were normalized to sea-level counting rates. The galactic counting rate background during a 4 h period order before the solar event was studied. This background galactic rate was removed from the data by subtracting, from each 5-min rate, a seven-point (35 min) sliding average. This sliding average was terminated at 1510 UT and the average was then extrapolated into the period of the solar event.

5-min average neutron monitor rates from Calgary and Sulphur Mountain, with the background removed as outlined above, are plotted in Fig. 2 for the period 1430–1600 UT. The 5-min average counting rates (with seven-point sliding averages removed) from Goose Bay and Deep River are also shown. The standard deviations of the counting rates, determined from the pre-1510 UT data, are indicated for each station, and the maximum H_α flare times as reported from Pic du Midi (UPIC), Boulder (Boul), and Anacapri (CAPF) are indicated, together with the flare maximum in the calcium II line as reported from Greenwich (HERS); the white light flare maximum from Sacramento Peak Observatory (ref. 7 and D. M. Rust, private communication); and the flare observations at Ottawa at 2.2 GHz (ref. 6).

The data from Sulphur Mountain and Calgary (Fig. 2) indicate that the neutron monitors at both of these stations began to record solar flare particles in the interval 1525–

1530 UT. The counting rate increase at Calgary was $\sim 1.7\%$ above the background; this corresponds to an increase of ~ 12 standard deviations above the mean. The counting rate increase at Sulphur Mountain was $\sim 2.3\%$ above the background; this corresponds to an increase of ~ 8 standard deviations above the mean. So the counting rate increases between 1525 and 1530 UT observed at both stations are highly significant on a statistical basis and can arise only from solar particles produced in the August 7 flare.

The neutron monitor at Deep River began recording statistically significant fluxes of solar particles in the interval 1530–1535 and the monitor at Goose Bay began to respond in the interval 1535–1540. Thus, of the four stations for which data are plotted in Fig. 2, both Calgary and Sulphur Mountain first observed solar particles, with solar particles being observed at successively later times at Deep River and Goose Bay, respectively.

The data of Fig. 2 suggest that the onset of the August 7 event at Earth was highly anisotropic, as might be expected. The observed rapid onset of particles at Calgary and Sulphur Mountain and the observed anisotropy can be understood by investigating the asymptotic directions of arrival for particles of various rigidities at the four stations (Fig. 3). The location of the Sun and the direction of the interplanetary field line near Earth are shown with these data in Fig. 3. The stations at Calgary and Sulphur Mountain were within $\sim 10^\circ$ of the field line near Earth for particles of ~ 3 –5 GV rigidity. For these particles the plot of asymptotic arrival directions indicates that both the Calgary and Sulphur Mountain monitors would be expected to observe an initially highly anisotropic solar flux before the monitors at either Deep River or Goose Bay. Also, for initial particles of this momentum, the Deep River monitor would be expected to observe the solar particles before Goose Bay. The observations (Fig. 2) and the asymptotic directions of arrival (Fig. 3) are therefore consistent with the conclusion that the initial solar flare particles had rigidities of ~ 3 –5 GV and propagated directly to Earth along the spiral interplanetary field line.

The similarities in times of observance of the shocks of August 4 and August 9 at Pioneer 9 and at Earth suggest that the time dependence of the solar wind speed at the Earth was similar to that at Pioneer 9 during the period August 6–9. In that case, at the time of the 3B flare on August 7, the interplanetary field line between Earth and the Sun was connected to the Sun at $\sim W 36^\circ \pm 2^\circ$. So the interplanetary field provided an essentially direct connexion between the flare site and the Calgary and Sulphur Mountain asymptotic arrival directions.

The length of the spiral field line from the Sun to Earth at the time of the August 7 flare can be calculated using the solar

wind speed observed on Pioneer 9 between 1500 UT on August 7 and 0400 UT on August 9. These speeds, viewed as a function of time, can be converted to a radial profile of the wind speed in interplanetary space. The time coverage of wind speed data before the August 9 shock is sufficient to determine the radial profile of the wind speed between ~ 0.4 a.u. (~ 300 km s $^{-1}$) and 1 a.u. (~ 550 km s $^{-1}$). We then assumed that the wind speed between the Sun and ~ 0.4 a.u. was a constant, equal to ~ 300 km s $^{-1}$. Using the radial profile thus obtained for the interplanetary solar wind speed, we determined an interplanetary field line length equal to ~ 1.12 a.u. between the Earth and the Sun at the time of the August 7 flare.

For a solar flare particle of ~ 4 GV momentum, $v/c \sim 0.97$. For a spiral field line length of ~ 1.12 a.u., the direct Sun–Earth travel time would be ~ 9.6 min, compared to a transit time of ~ 8.3 min for electromagnetic radiation. Any diffusion by these initial protons, either in the corona or in interplanetary space, would increase the travel time. Thus, the data presented here are direct evidence that relativistic protons were present on the Sun ≥ 5 min before the flare maximum as recorded by both radio and optical techniques and were present within a minute or two of the white-light maximum.

In conclusion, the observations presented here clearly show that, for this flare, particle acceleration and injection into interplanetary space occurred before the explosive (H_α maximum) phase of the flare. The near coincidence of the white-light flare and the time of particle injection supports the view that the white-light flare results from the dumping of relativistic particles into the photosphere⁴. The observations do not permit a conclusion as to whether the particles were accelerated and dumped, as well as injected, during the white-light phase⁸ or whether they were accelerated before the time when they were released^{9,10}.

The injection of relativistic particles before the H_α maximum phase may well be a general rule rather than a special case. If so, this result has important implications for the study of relativistic solar particle propagation. In these studies, the H_α maximum is most often taken as the time of particle injection when performing fits of various diffusion models to the onset phase of a particle event (see, for example, ref. 11). If, as a general rule, relativistic solar particles are released ≥ 5 min before the H_α maximum, some of the interplanetary diffusion coefficients κ_{11} inferred in the past from the time-to-maximum t_m of particle intensities will be in error by $\geq 50\%$ because $\kappa_{11} \propto t_m^{-1}$.

Our measurements were fortuitous in the sense that the asymptotic arrival directions of Sulphur Mountain and Calgary were essentially “connected” to the flare region by the spiral interplanetary field lines. Further, the interplanetary space propagation was undoubtedly aided by the existence of the Forbush decrease^{12,13}. Details of the particle propagation and the implications of the measured anisotropies for coronal diffusion and transverse interplanetary diffusion will be reported later.

We thank Professor D. Venkatesan and Drs R. W. Kreplin, K. G. Frost and D. M. Rust for discussions, and Dr J. F. Steljes for providing the Deep River and Goose Bay data. The work at Calgary was supported by NRC grants.

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Received November 16, 1972.

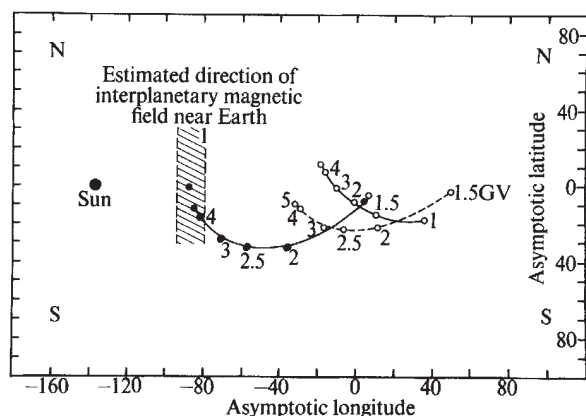


Fig. 3 Asymptotic directions of arrival¹⁴ for relativistic particles of various rigidities incident at Sulphur Mountain, Calgary (●—●), Deep River (○—○), and Goose Bay (○—○) at 1530 UT. Location of Sun and of interplanetary field line between the Sun and the Earth also shown.

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Difficulties concerning a Finite Photon Rest Mass

Pecker, Roberts and Vigier have suggested that much, if not all, of the cosmological redshift might be attributable to inelastic photon-photon scattering—if the photon possesses a finite rest-mass¹. Pecker and Vigier have attempted (private communication) to apply Vigier's ideas to the electromagnetic propagation anomalies observed by Sadeh and others^{2,3}. We agree in part with the ideas of Vigier and his co-workers, but their hypothesis, as regards these phenomena, cannot be completely correct as stated.

For the case of the cosmological redshift Pecker *et al.* note that, had the photon a finite rest-mass, inelastic photon-photon scattering of extra-galactic photons on the photons of the cosmological black-body background radiation should occur. By successive interactions a photon should be progressively reddened, they claim, as it travels through inter-galactic space. They propose, in effect, a partial mechanism for the well-known "tired light" hypothesis. We have investigated the tired light hypothesis as a possible solution of the so-called "missing mass" problem⁴. It seems that the assumption of the tired light hypothesis is a workable solution of that problem. Insofar as this is the case, this solution of the missing mass problem is indirect, supportive evidence for Vigier's hypothesis.

But the mechanism of Pecker *et al.* is defective because it only partially meets the requirements of a tired light effect. Their hypothesis does not avoid the most critical problem of all non-Doppler explanations of the cosmological redshift: Olbers paradox. Although they have advanced a plausible mechanism for the reddening of individual photons, a mechanism for the reduction to the observed level of the total electromagnetic energy flux incident on the Earth from extra-galactic sources is absent. If a mechanism cannot be devised to achieve this reduction, then inelastic photon-photon scattering must be rejected as the source of the cosmological redshift. (Perhaps this difficulty might be avoided by taking the electromagnetic field to be a finite range, Yukawa type field by, for example, substituting a Yukawa potential for the Coulomb potential.)

As regards electromagnetic propagation anomalies in the solar environment, Pecker and Vigier's proposed effect is the same as that proposed for the cosmological redshift. But now the solar electromagnetic radiation field replaces the cosmic background radiation. They deduce that scattering on this field should lead to a reddening of electromagnetic radiation from planetary and stellar sources as they appear to pass near the Sun. Thus, for Sadeh's observations of the 21 cm line of Taurus A, Pecker and Vigier predict a frequency shift, the maximum shift being about 100 Hz.

Such an explanation of Sadeh's effect would be pleasing were it not for the observations carried out by Goldstein and Levy *et al.*^{5,6}. They made long-term observations of the various properties of the plane-polarized, unmodulated 2.3 GHz carrier signal of Pioneer 6 as it approached and receded from occultation by the Sun. They observed several unexplained, periodically recurring transient propagation anomalies, but no

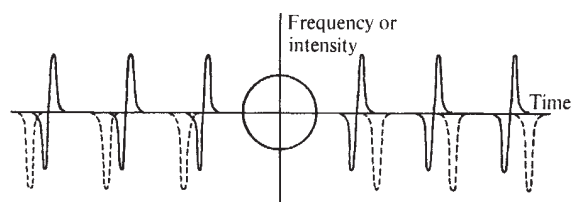


Fig. 1 Schematic diagram of the only type of propagation anomalies in the solar region consistent with the observed anomalies (refs. 5 and 6) and not at variance with other available empirical results.

long-term alterations in the signal properties that could not be ascribed to simple causes.

To test if the various propagation anomalies are the result of an anomalous photon-graviton interaction, we have investigated to see whether transient propagation anomalies (Fig. 1) are manifested in the optical-frequency deflexion observations. The results seem to be positive⁷. Transients of this sort seem to be the only type of propagation anomalies compatible with all available observations, those of Sadeh and Goldstein included. If such transients exist, whether they are the result of photon-photon and/or photon-graviton scattering is impossible to say at present. But, irrespective of the possible existence of these transients, Pecker and Vigier's hypothesis, as currently formulated, is inadmissible on the above empirical and theoretical grounds. If inelastic photon-photon scattering takes place, the mechanism must be more complex than that advanced by Pecker and Vigier.

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Photon Mass, Quasar Redshifts and Other Abnormal Redshifts

As stated in a recent *Nature* editorial¹ "the first claims that quasar redshifts were not caused by Doppler velocities of recession were met with general disbelief". In spite of this, experimental evidence has been accumulating in favour of such non-velocity shifts (see, for example, refs. 2, 3). Burbidge (unpublished) has shown a significant anti-correlation between the apparent distance of a quasar and a nearby galaxy and the brightness of that galaxy (hence a correlation with its distance): this suggests a physical association, in many cases, between two objects, a QSO and an ordinary galaxy, displaying very different redshifts.

Here, we discuss the application to quasars of a mechanism⁴ which provides a simple explanation of the essential observational paradoxes which have prevented a coherent understanding of the nature and distance of QSO sources.

The new mechanism rests on the possible existence of a non zero photon mass $m_\gamma < 10^{-48}$ g. We prefer this mechanism to others (such as Hoyle and Narlikar's⁵) because this one explains not only the QSO redshifts but several other phenom-

ena, with the same value of the phenomenological constant of our formula.

Flato and Vigier (unpublished) show how one can generalize to photon-photon interaction from an interaction scheme discussed by Corben and Schwinger⁶ for spin 1 mesons; we introduce inelastic photon-photon collisions which yield a constant fractional energy loss cross section independent of the photon energy, have a very strong forward peak and do not invalidate quantum electrodynamics, provided one utilizes suitable form factors which drop sharply off the mass shell.

In other words, a background transverse photon exchanges a virtual longitudinal photon (in its rest frame) with an incoming transverse photon and produces a soft transverse photon pair. This implies that transverse photons crossing a transverse radiation field lose energy according to the law

$$\delta z = \delta p / \gamma = - \int c U(p) dp \quad (1)$$

where $U(p)$ represents the photon density, dp the distance therein and c a constant which should be determined by experiment. This theory might somewhat modify our ideas concerning the expansion of the Universe. So far, we claim only that, in addition to the cosmological redshift, there exists, particularly strongly in quasars, another source of redshift, the photon-photon interaction. As to the expansion, we think that a revision of the Hubble-Sandage scale is not to be ruled out, on the basis that usual determinations assume more or less an identity in physical properties for close by galaxies and for the most remote ones: for example, why should the absolute size of H II regions be the same for young and old galaxies? We have indeed some good reasons to believe the contrary. In that case, an increase of the Hubble constant from 50–100 km s⁻¹ Mpc⁻¹ to 100–200 km s⁻¹ Mpc⁻¹ would bring back the cosmological temperature derived from our value of A to a value compatible with both expansion and photon-photon interaction. We note that our interpretation does not modify the classical interpretation of Olbers paradox: any source of redshift, cosmological or not, would give the same solution. In a blackbody radiation field equation (1) becomes

$$\delta t = - \int A T^3(p) dp \quad (2)$$

where T represents the background temperature and A a phenomenological constant.

We can determine the constant A by using measurements of redshifts in some conditions better known than those in QSOs.

We have found that the value determined for A , from different astrophysical observations, is: (i) Redshift of the Fraunhofer lines at the disk limb of the Sun, as measured by Roddier⁸

$$0.6 \times 10^{-29} \leq A \leq 3 \times 10^{-29} \text{ K}^{-3} \text{ cm}^{-1}$$

These measurements are impossible to interpret as the result of any other effect⁹. Snider¹⁰, using other lines, did not find this effect, but it seems to us that Roddier's experiments have a better accuracy, (ii) redshift of the 21 cm line of a radio source occulted by the solar atmosphere^{11,12}

$$1.4 \times 10^{-29} \leq A \leq 7 \times 10^{-29} \text{ K}^{-3} \text{ cm}^{-1}$$

(iii) If we interpret the Hubble redshift as due to, at least in part, the effect we invoke, it gives indeed an upper limit to A ; if the Hubble constant $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$

$$A \leq H_0 / T^3 = 2.7 \times 10^{-30} \text{ K}^{-3} \text{ cm}^{-1}$$

assuming $T = 2.7 \text{ K}$ for the cosmological radiation field. To obtain a value of A consistent with (i) and (ii) we require, say, $T = 2.2 \text{ K}$ and $H = 100$; we would then get $A \leq 10^{-29}$. The accepted value of the Hubble constant may be questioned, which would completely reconcile the observed value of 2.7 K for the cosmological temperature and our limits for A , provided $H \gtrsim 180 \text{ km s}^{-1} \text{ Mpc}^{-1}$. The Hubble constant has recently been revised downwards taking into account, notably, the size of

large H II regions. This size may be a function of the degree of evolution of the galaxy, through the stage of quasars¹³, so the more recent evaluations of the Hubble constant may have been incorrectly biased, and we feel that the value 200 km s⁻¹ Mpc⁻¹ is not to be ruled out.

Our mechanism adds two astrophysical processes to the well known sources of redshifts, both consequences of the photon-photon interactions: first, a redshift associated with the travel of photons from a remote source to the observer, through the interstellar microwave field of 2.7 K or so; second, a "source" redshift associated with the existence of a photon bath surrounding radiating sources—which can be small (Sun) or extended (some galaxies, quasars); if R_s is the radius of the radiating source, the effect is of the order of

$$\delta z \cong - A T_s^{-3} R_s$$

assuming a blackbody radiation field for the source.

If one accepts the observed z values as reflecting true distances (from expansion theory) quasars should have luminosities a hundred or a thousand times brighter than those of normal galaxies. The existence of usual carbon and magnesium lines at such energies is very difficult to understand. Further QSOs are evidently condensed objects (with $R_s \ll 1 \text{ pc}$). From the observed time variation of their optical and radio brightness it seems that the regions which produce the observed energy have a maximum diameter of a few light day ($R_s \sim 10^{15} - 10^{16} \text{ cm}$); it is difficult to construct energy generation mechanisms that could work under such restrictions. Successful attempts have been made, but they seem to us rather artificial and *ad hoc*. The situation is different from our point of view. If the essential part of QSO redshift results from the slowing down of emitted photons by the radiation field surrounding the source, one explains immediately Arp's empirical observation³ that QSOs are associated with nearby galaxy chains and clusters and seem to avoid all distant systems of galaxies. QSOs become "normal" objects: the distribution in the sky of QSOs of the brightest apparent magnitude is associated with the local group of galaxies; the distribution of fainter QSOs is associated with more distant but still nearby galaxies in the local supercluster.

We suggest that QSOs are extended structures, with massive cores and a relatively high average temperature, and surrounded by a transparent region, where the size of the photon bath has the same order of magnitude of the size of the QSO ($10^{15} \leq R_s \leq 10^{16} \text{ cm}$). The temperature we assume for the QSO core or cores is about $10^4 < T_s < 10^5 \text{ K}$, a range of values derived from the observed blue colours of these sources.

With $A \sim 2 \times 10^{-29}$, $T_s = 2 \times 10^4$ and $R_s = 5 \times 10^{15}$ the obtained value for z , according to equation (2), will be 0.8, a sensible average value for QSOs.

Because z essentially results from variations of the surface radiation temperature we expect that if our assumption is correct we should observe something like a Gaussian distribution of the numbers of QSOs around this average equilibrium value T_s . To test this, the best method is to plot the number N against the values of T according to equation (1). This can be done by transforming the empirical curve $N(z_y)$ established by Roeder and Dyer¹⁴ which takes into account the probable effects of the terrestrial atmosphere on QSO redshift measurements. Starting from the best fit curve of Fig. 1, we obtain the curve $N(T)$ by the cubic root of the z_y values of Fig. 1. This yields indeed a symmetric curve peaked around the value $T_0 \sim 10^4 \text{ K}$.

We have accepted here the argument of Roeder and Dyer that the curve has only one maximum, the two other observable maxima resulting from observational bias. If it turns out that there exist other real peaks (such as the apparent peak around $z_y = 2$), these could be interpreted as corresponding to other types of objects differing by the equilibrium temperature, that is, by the extent of the ionization regions to part or all of the young galaxy which we suggest is a QSO. Further, the cutoff of N for $z_y > 2.3$ results naturally from our model. Values

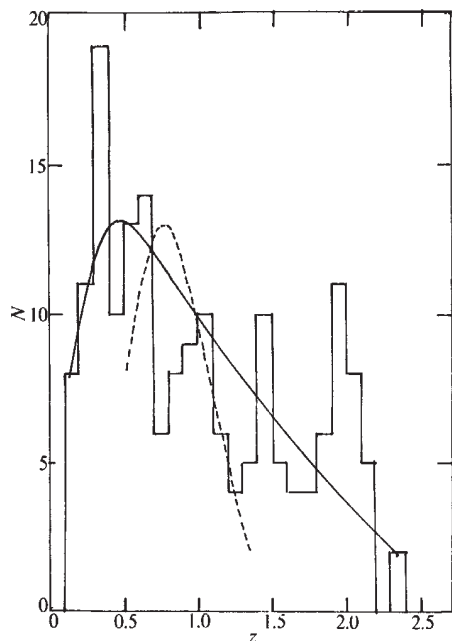


Fig. 1 The distribution of 178 quasar emission line redshifts together with the smoothed distribution (—) of Roeder and Dyer. The dashed line (---) corresponds to their distribution with $Z^{1/3}$ proportional to T .

of $z_q > 2.3$ are not probable. Because we are observing only a finite set of QSOs in our local supercluster and no observations are yet possible in the other superclusters the cutoff reflects the limited nature of the observable sample.

The fact that the value for z_q , $z_q(\text{obs})$, deduced from absorption lines, approximately coincides with the z_q deduced from emission features is also natural if one assumes that the emission and absorption both take place near the emitting core or cores of the QSO, as in the model recently proposed by Schmidt¹⁵ which yields for the average value of the QSO mass $5 \times 10^{12} M_\odot$. This is consistent with the description of QSOs as young galaxies.

A simple independent quantitative analysis of typical QSO energy balances strongly supports this model. In order to fit the brightest QSO in apparent magnitude (3C 273) in an observed galaxy chain one must reduce its distance by about a factor 10^2 . It thus radiates $10^{43} \text{ erg s}^{-1}$ (instead of the generally assumed 10^{47}) which corresponds to a surface flux of $F_{\text{QSO}} = 10^{43}/(4\pi \times 10)^{30} \sim 10^{12} \text{ erg s}^{-1} \text{ cm}^{-2}$. The solar surface flux $F_\odot = 10^{33}/(4\pi \times 36 \times 10)^{20} \sim 10^{10} \text{ erg s}^{-1} \text{ cm}^{-2}$. The surface temperature of the QSO core or cores is thus $\sim 10^{40} \text{ K}$ in good agreement with our determination.

If QSOs are young galaxies with a condensed central core, or cores, whose surface produces the observed emissions and with a rather hot surrounding "bath" of photons corresponding to an average temperature of 10^4 to 10^5 K , and they are almost normal objects, containing the usual elements observed in the "cooler" older type of galaxies, then there exists, in Arp's words, "a continuity of physical characteristics going from quasars through compact galaxies to companion galaxies".

We suggest that, as a consequence of differences of temperature of their radiation field, QSOs seem to have larger redshifts but companion galaxies also have higher redshifts than the accompanying galaxies because they are in a "hotter" younger form. Their formation is linked to the earlier stages of the evolution of the protogalaxy towards a normal galaxy through a production mechanism of the type suggested by Pecker¹³.

Further, QSOs do not belong to an autonomous very distant population of objects but are generally associated with galaxy chains and clusters observed in the same direction. This means that their "true" distance is from 10 to 1,000 times smaller than is generally assumed at present. This suppresses many difficulties; (because the total energy produced is reduced, the

known pairs of sources as in 3C 379 which seem to separate at velocities of the order of $10c$ are at least 10 to 100 times closer than we thought, and strange anomalies such as the large apparent radii of some quasars (discussed by Miley and quoted in ref. 3) disappear.

In our model, the process of galaxy creation is such that QSOs, compact galaxies, blank field radio sources, luminous material, lines of galaxies and companion galaxies result from ejection in opposite directions from the nuclei of large young galaxies. Spiral galaxies, galaxies which are ejecting or have ejected material in opposite directions, would naturally contain a hotter radiation field than amorphous elliptical galaxies; so that Jaakala's results² are also encompassed by our new redshift mechanism.

Finally, in this model the radio-emission by QSOs is due to the long wavelength component of the spectrum emitted by the photon-photon interactions. A photon from the source collides with a photon from the field and they produce a group of three types of particles: two very low (radio) energy photons, a reddened photon, and the perturbing photon. The theory of the radio-emission must be derived from the theory of photon-photon interaction; but clearly it will not produce a thermal radio-spectrum.

Although, in this construction, each argument taken separately may not be entirely convincing, we feel that a set of converging arguments gives our views an exceptional coherence, and a larger amount of credibility than other theories.

We thank Professor Papapetrou, Dr J. Madore and C. Dyer for helpful discussions.

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Received October 16, 1972.

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Comment on "Non-Velocity Redshifts and Photon-Photon Interactions"

It has been claimed recently¹ that some redshifts can be explained by considering a new type of process in which the incident photon scatters inelastically on the 3K radiation to give four less energetic photons. The Lagrangian responsible for the interaction is taken as $\Lambda(A_\mu A^\mu)^2$ and the process is considered in the second order only to account for the necessary

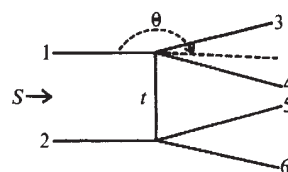


Fig. 1 Diagram of the process.

strong peaking of the cross-section (see Fig. 1). Here we describe the detailed calculation of this process

The differential cross-section is given by

$$d\sigma = \frac{1}{4\omega_1\omega_2} |\mathcal{M}|^2 (2\pi)^4 \delta^4(p_1 + p_2 - \sum_{i=3}^6 p_i) \prod_{i=3}^6 \frac{d^3 p_i}{(2\pi)^3 2\omega_i} \quad (1)$$

where ω_i and p_i are the energies and momenta of the external photons. The invariant matrix element $\mathcal{M}$ is given in terms of the polarization vectors ε^i and the exchanged momentum squared t by

$$\mathcal{M} = 64 \Lambda^2 \varepsilon_\mu^1 \varepsilon_\nu^2 \varepsilon_\alpha^3 \varepsilon_\beta^4 (g^{\mu\nu} g^{\alpha\beta} + g^{\mu\alpha} g^{\nu\beta} + g^{\mu\beta} g^{\nu\alpha}) \frac{g_{\lambda\tau}}{t} \varepsilon_\alpha^5 \varepsilon_\beta^6 \varepsilon_\gamma^7 \varepsilon_\delta^8 (g^{\alpha\beta} g^{\gamma\delta} + g^{\alpha\gamma} g^{\beta\delta} + g^{\alpha\delta} g^{\beta\gamma}) \quad (2)$$

Averaging over polarizations yields

$$|\mathcal{M}|^2 = \frac{72 (64 \Lambda^2)^2}{t^2} \quad (3)$$

Putting $(p_1 + p_2)^2 = S$, $(p_3 + p_4)^2 = \mu^2$, and $(p_5 + p_6)^2 = \mu'^2$, one gets in the centre-of-mass frame for $\mu^2, \mu'^2 \ll S$

$$\frac{d\sigma}{2\pi d\cos\theta d\omega_3 d\omega_4} = \frac{1}{4\omega_1\omega_2} |\mathcal{M}|^2 \frac{1}{(4\pi)^6} \frac{1}{[\omega_3^2 + \omega_4^2 + \omega^2 + 2\omega_3\omega_4 - 2\omega_3\omega - 2\omega_4\omega]^{-1}} \frac{1}{|f'(\omega)|} d\mu^2 d\mu'^2 \quad (4)$$

where $f(\omega) = \omega_1 + \omega_2 - \omega_3 - \omega_4 - \omega - [\omega_3^2 + \omega_4^2 + \omega^2 + 2\omega_3\omega_4 - 2\omega_3\omega - 2\omega_4\omega]^{1/2}$

$$f'(\omega) = \frac{\partial f}{\partial \omega}$$

and ω is the positive root of $f(\omega) = 0$ (if it does not exist $d\sigma = 0$). θ is the scattering angle for the quasi-elastic process.

A simple integration over μ^2 and μ'^2 , restricting μ^2 and μ'^2 to values less than K (small compared to S), gives

$$\int_0^K \int_0^K \frac{d\mu^2 d\mu'^2}{t} \sim \frac{4}{\cos\theta} \int_0^{\frac{2K^2 \cos\theta}{S^2}} dX \log \left(\frac{K}{S} \sqrt{\frac{2 \cos\theta}{X}} \right) [1 - \cos\theta + X]^{-2} \quad (5)$$

which behaves as $-\frac{2}{1 - \cos\theta} \log(1 - \cos\theta)$ when $\theta \rightarrow 0$.

Consequently such a process does not lead to strong peaking in the forward direction, which is necessary in order to get a point-like image of the source. (In the laboratory frame the angular dispersion is reduced merely by a factor of 0.5.) Moreover, it is obvious from equation (4) that there is no well-defined redshift independent of the frequency of the incident photon. Instead, because the cross-section is an algebraic function of the final energies, the frequency response is predictably spread all over the available phase-space, giving grey radiation rather than a shifted line.

We therefore conclude that this process cannot account for any observed redshift.

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Received November 20, 1972.

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Photochemical Ozone Formation in the Atmosphere over Southern England

ATKINS *et al.*¹ present evidence of photochemical ozone formation in the atmosphere over southern England. When, however, the diurnal ozone variation is carefully examined, some doubt may be felt whether all the ozone measured was indeed locally generated. The data given by Atkins *et al.* include thirteen days where pronounced ozone peaks could be observed and in all these cases the maxima occurred in the late afternoon, between 1600 and 1700 BST. These late afternoon maxima are not in accord with the predicted diurnal variation of photochemically produced ozone; the daily maxima should appear between 1200 and 1400 local standard time, when the combination of high insolation and temperature leads to enhanced ozone production².

Continuous ozone and oxidant measurements performed in Los Angeles³, Aspendale, Australia⁴, and Jerusalem⁵ demonstrate that peak concentrations do indeed always occur soon after local noontime. Fig. 1 shows the detailed variation of oxidant concentration, insolation and vehicle density (at the site of measurement) in Jerusalem for a typical day in July. The vehicle density was approximately constant and the oxidant concentration curve follows the insolation curve with a displacement of two hours at most. The Los Angeles data³ exhibit the same behaviour exactly.

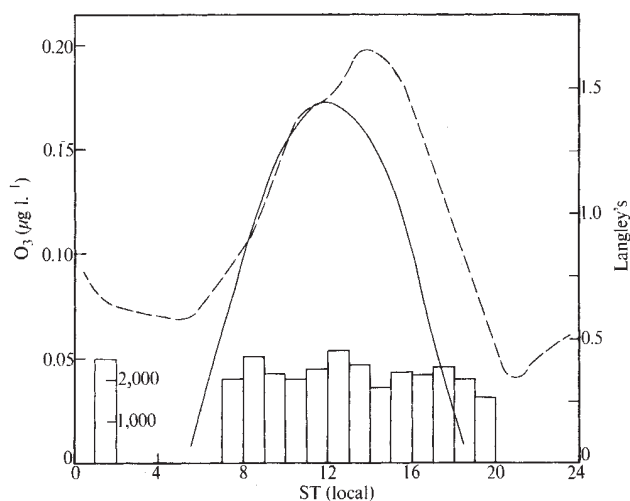


Fig. 1 Diurnal variation of oxidant concentration, insolation and vehicle density. Oxidant concentration is given by $\mu\text{g l}^{-1}$. ---, Ozone concentration; —, insolation.

If all the ozone recorded at Harwell were produced locally by photochemical reactions, the same diurnal pattern would be expected. The discrepancy between the expected and observed pattern may be explained in part if the relevant meteorological conditions are taken into account. Synoptic data for July 3, 1971, show the existence of a low inversion (700 m), high surface temperature and pressure and weak winds, conditions leading to elevated pollutant concentration over southern England. For July 7 meteorological data are not given, but from the daily weather report of the British Meteorological Office we found that conditions were again favourable for increased ozone production. On the other hand on June 26 synoptic data show high inversion, low pressure and temperature and westerly winds. The ozone values were much lower, and the maximum appeared at about 1400 BST.

Because photochemically produced ozone should attain its highest concentration in the early afternoon, it seems clear that some other mechanism is responsible for the delayed maxima measured at Harwell. We suggest that these maxima are due not only to increased local production but also to advection of ozone from the London Metropolitan area, where ozone

generation was also enhanced, as the same meteorological conditions prevail at both places.

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Received September 26, 1972.

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Elevated Ozone Levels in the Air of Central London

AMONG the reactions of primary pollutants with one another and with substances naturally present in air, the reactions induced by light are particularly important. The occurrence of such reactions is related to the accumulation of strongly oxidizing species, particularly ozone¹, which occurs naturally in the atmosphere to the extent of 20–50 p.p.b. during daylight^{2,3}. Ozone can be detected by smell by sensitive individuals at 100 p.p.b.⁴, which value is a suitable threshold for an air quality evaluation, having been proposed as an air quality standard in the USA⁵.

Table 1 Ozone and Meteorological Data for July 12 to 14, 1972

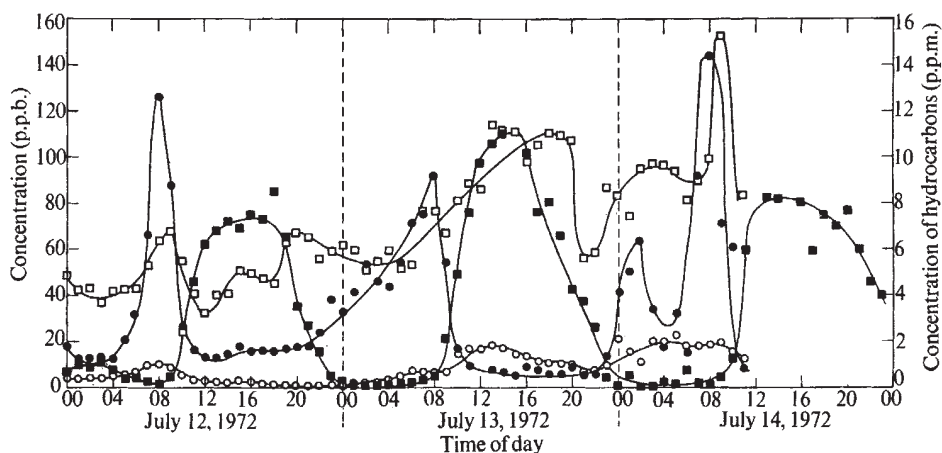
	July 12, 1972	July 13, 1972	July 14, 1972
Ozone concentrations:			
Maximum value (p.p.b.)	99.6	112.0	102.2
Maximum hourly average (p.p.b.)	85	111	83
Mean daily concentration (p.p.b.)	33	43	38
Number of minutes above 100 (p.p.b.)	0	250	10
Meteorological data for Kew, London, at mid-day ⁶			
Wind speed, knots	5	0	7
Temperature, °C	21	22	23
Dewpoint temperature, °C	9	9	12
Visibility, km	20	11	11
Number of sunshine hours	13.2	10.2	13.0

concentrations now reported are higher and represent the first measurement of photochemical air pollution in a British city.

The weather conditions which lead to the formation of photochemical air pollution include sunlight and light wind or calm conditions. We find at midday on July 13, 1972, and July 14, 1972, and July 3, 1971, at Harwell, wind speeds were force 2 or less, cloud cover was 2/8 or less and temperatures were 18° C or more.

A search of meteorological records for the past ten years has shown that the above conditions prevailed at midday at Heathrow, London, on 15 occasions in the months April to September (J. Briggs, private communication). Consideration of the rate of increase in the ozone concentration on July 13 in the period between 1000 h and 1600 h (28 p.p.b. h⁻¹, Fig. 1) would indicate that two hours of suitable meteorological

Fig. 1 Diurnal variations of air pollutants measured in London from July 12 to July 14, 1972. ■, Ozone, p.p.b.; ●, nitric oxide, p.p.b.; □, nitrogen dioxide, p.p.b.; ○, hydrocarbons, p.p.m.



This laboratory is currently monitoring the air quality in respect of a number of pollutants at its laboratory in Endell Street, Holborn, London. The pollutants include ozone, nitric oxide, nitrogen dioxide, carbon monoxide, total gaseous sulphur compounds and total gaseous hydrocarbons. The sampling point is away from traffic and is not influenced by a specific pollutant source; it is representative of the background air in Central London.

The concentration of ozone measured from July 12 to 14, 1972, at this site is given in Table 1 together with the meteorological data for these days. The diurnal variation in the concentration of ozone and other pollutants during July 12, 13 and 14 is shown in Fig. 1. The variation in concentration of the pollutants during daylight is typical of photochemical processes⁴. Values for ozone concentrations in excess of 100 p.p.b. were first recorded in the United Kingdom at Harwell, Berkshire, on July 3, 1971, and July 7, 1971 (ref. 7). The ozone

conditions in this period would be sufficient to cause the ozone concentration to exceed 100 p.p.b. at present levels of nitric oxide and hydrocarbon emission. Data on the frequency of such periods are not immediately available.

On July 25, 1972, there was 4/8 cloud cover at midday but this had decreased to less than 2/8 by 1300 h. The ozone concentration rose and had exceeded 100 p.p.b. for 20 min by 1600 h. The wind speed was less than force 2 and the temperature over 18° C as before.

Measurements are continuing and a more detailed discussion will be presented later.

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Received October 6, 1972.

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BIOLOGICAL SCIENCES

Papova Virus in Urine after Renal Transplantation

THE excretion of viruses of the papova type in urine following renal transplantation has been described only in a single case¹. Excretion of herpes viruses is more common, and a high incidence of warts in transplant patients has also been reported². A papova-like virus has been found in brain material of patients with progressive multifocal leuco-encephalopathy (PML) and such viruses have been cultured from cases of PML complicating Hodgkin's disease^{3,4}. Immuno-suppressive therapy activates latent viruses⁵ and is associated with a high incidence of malignant tumours⁶. We report here the excretion in urine of a papova-like virus by approximately 45% of patients in a renal transplant unit.

The patients (Table 1) had received renal allografts between thirteen and twenty-two months before the start of the investigation. Thirteen patients received kidneys from dead donors, four had kidneys from living donors, while one patient received a second kidney (from his mother) after removal of a rejected kidney from a dead donor. The standard immuno-suppressive maintenance therapy consisted of irradiation (150 rad) on days 1, 3 and 5 after transplantation, azathioprine ('Immunar'), prednisolone and horse antilymphocyte serum (Behringwerke).

Urine specimens from transplant patients were taken at weekly intervals, and samples from eight staff members of the transplant unit were investigated at least once during the period of June 21, 1972, to August 1, 1972. Urine (12 ml. aliquots) was centrifuged within 1 hour of collection at 32,000 g in a 'Beckman model A' centrifuge ('type 40' rotor) for 1 hour. The pellet was resuspended in 12 ml. distilled water, and centrifuged in the same way. The supernatant was decanted and the pellet used for electron microscopy. Samples of antilymphocyte serum (1 ml.) used in the treat-

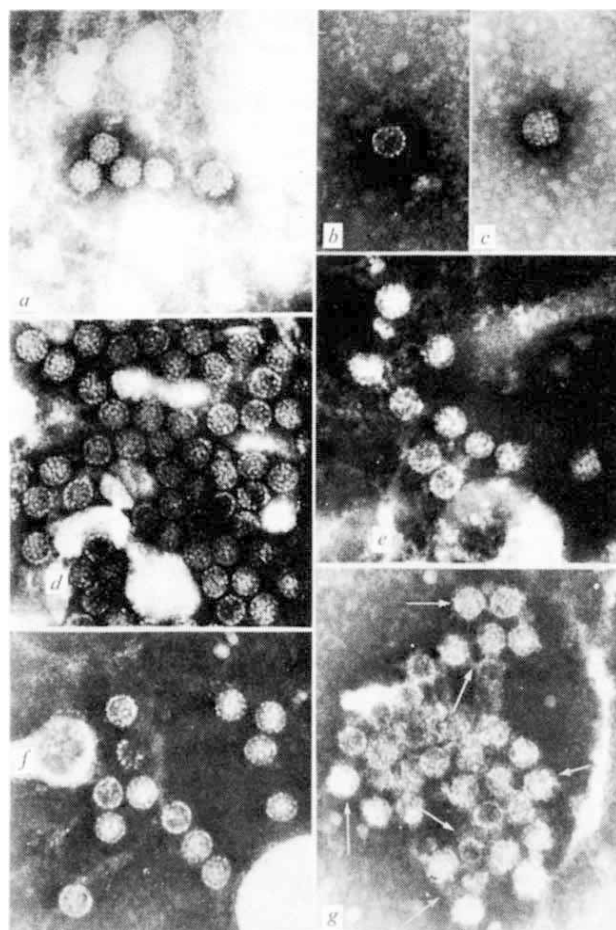


Fig. 1 *a-f*, Papova-type virus particles. A small portion of the pellet from centrifuged urine samples was taken up in a drop of distilled water and this suspension mixed with a drop of 3% (w/v) phosphotungstic acid at pH 6. A drop of this mixture was put on to a 'Formvar'-carbon coated grid, the excess fluid removed with filter paper and the grid allowed to dry. Preparations were examined in a 'Siemens Elmiskop 1A' electron microscope at 80 kV at $\times 40,000$. Particle diameters were measured on negatives employing a 'Nikon model 6C' comparator. The figures *a-f* correspond to the virus positive patients CD4, CD6, CD6, CD11, CD14 and CD18 respectively as shown in Table 1. $\times 96,000$. *g*, Immune electron micrograph. Serum from patient CD11 taken on June 14, 1972, was diluted 1:4 in distilled water. A portion of the pellet obtained from her urine was mixed with a drop of the diluted serum, stained and examined as before. Note clustering of antibody-coated virus particles. Viral antibody indicated by arrows. $\times 96,000$.

Table 1 Patients and Detection of Virus Particles

Patient	Age and sex	Date of transplant	Date of virus detection	Virus diameter (nm)
CD4	40 (M)	September 17, 1970	July 5, 1972	45 ± 0.4
CD6	44 (F)	November 24, 1970	July 18, 1972	48^*
CD11	58 (F)	July 15, 1971	June 28, 1972	43 ± 1.7
CD14	28 (F)	October 3, 1971	July 18, 1972	47 ± 1.9
CD18	49 (M)	March 3, 1972	July 24, 1972	48 ± 1.6
CD2-LD3	32 (M)	April 11, 1970	July 24, 1972	43^*
LD2	15 (M)	May 7, 1971	August 1, 1972	43^*
LD5	38 (F)	January 15, 1971	August 1, 1972	43^*
		March 1, 1972		

CD=Patient received kidney from dead donor.

LD=Patient received kidney from living donor.

*=Insufficient particles (less than 4) for s.e. determination.

ment of the patients were made up to 12 ml. with distilled water and examined for virus particles in the same manner. Serum and virus positive urine pellet from patient CD11 was used for immune electron microscopic studies.

Details of the patients, dates of transplants, dates of initial and subsequent virus detection and virus particle size are given in Table 1. Particles with the typical morphology and size of the polyoma group⁷ were seen in the urine of eight (44%) of the patients (Fig. 1*a-f*). The concentration of virus present varied from patient to patient, some showing only a few particles while patient CD11 excreted the largest number of particles (Fig. 1*d*). Three of the patients were virus-positive on more than one occasion. The particles correspond in size to the polyoma-SV40 sub-group⁷ and have the typical morphology. Those particles showing slightly larger diameters presumably represented partially collapsed capsids.

Patient CD11 excreted a herpes-type virus and was subsequently found to be positive for cytomegalovirus. One of the papova-negative patients was found to excrete an un-

identified icosahedral virus particle having a diameter of approximately 53 nm, but the morphology of this particle did not resemble that of the papova group. Polyoma virus is characterized by the presence of aberrant tubular forms of the capsid⁷; the absence of these in our investigations suggested that the particle is more like SV40 which lacks such tubes. Urine of eight staff members working in the unit contained no virus and no particles were observed in the antilymphocyte serum. The serum of patient CD11 whose urine contained the largest number of particles was shown to contain antibody against them (Fig. 1g). Antilymphocyte serum preparations did not contain antibody.

The fact that there was no apparent correlation between virus occurrence and date of transplant in the patients suggested that virus excretion occurred at intervals depending on antibody status. Regular screening of urine specimens should provide information in this respect. The form of immunosuppression given may be significant, supported by the fact that the patient of Gardner *et al.*¹ does not appear to have received any antilymphocyte serum. It is interesting that approximately 150 urine specimens from 31 kidney transplant patients examined by one of us (G.L.) during 1971 at Hammersmith Hospital, London, contained no papova-like particles. These patients, too, received no antilymphocyte serum. In a separate study, electron microscopic screening of urine from an equivalent number of Hodgkin's patients (18) not receiving antilymphocyte serum has yielded negative results with respect to papova-type particles so far.

The particles found in the present investigation seem to be similar to the "B.K." virus of Gardner *et al.*¹, which is substantiated by their size and morphological characteristics. Work on the culture and serology of the virus is in progress, in order to compare it with that found in cases of PML³.

Our patients have limited contact with each other and because no virus particles could be found in urine from staff of the kidney unit it was likely that the virus represented a latent human virus activated by immunological means⁵. The high incidence of virus-positive patients is worthy of note. We consider it remarkable that the polyoma-type particles are significantly more prevalent than other cubic virus forms which suggests that, if this is not fortuitous, then presumably a delicate balance in the immune system has been disturbed which has favoured the multiplication of this virus.

Follow-up of these patients may yield information about a possible relationship between virus excretion and the development of malignant tumours⁶. Experiments to determine the ability of the virus to transform cells and its possible oncogenic potential are envisaged.

We thank Dr W. H. F. Kenny (H. F. Verwoerd Hospital), Dr K. E. Weiss (Veterinary Research Institute, Onderstepoort) for facilities provided and Professor J. N. Coetzee for his comments.

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Received September 18, 1972.

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Diploidy and Chromosomal Structural Hybridity in *Phytophthora infestans*

IN the midst of some controversy, cytological and genetical evidence is accumulating to support the view that, in contrast to other fungi, the Oomycetes resemble higher organisms in being diploid in the vegetative state with meiosis occurring prior to gamete formation¹. However, there is still little cytological information available for many important fungi in this group. Outstanding among these is the potato blight fungus, *Phytophthora infestans*.

We have made a cytological examination of the gametangia (antheridia and oogonia) of *P. infestans* formed on crossing isolate 63B (compatibility type A¹) with isolate 445 (A²), and in cultures of 445 induced to self by the *Trichoderma* method². These isolates have been widely used in earlier genetical work on this species³⁻⁶.

In both types of material, crossed and selfed, two nuclear divisions normally occurred in the gametangia, and stages in meiotic prophase were observed. The chromosome number of *P. infestans*, from counts of first metaphase configurations, is 16-20 (2 (9 ± 1)).

Multiple associations of chromosomes were observed in some of the nuclei of the oogonia in both the paired and selfed material, and afford evidence that the divisions are indeed meiotic. The observation in several cases of an association of six chromosomes in the crossed material (Fig. 1) would seem to be evidence for structural hybridity rather than polyploidy. Thus one of the parents of the cross is believed to be a structural hybrid for a double interchange of chromosome parts involving three pairs of chromosomes, probably strictly analogous to that obtained in *Pisum sativum* and other higher plants when two single interchange lines are crossed⁷. Although selfed material of 445 was scanty, a multiple association was observed there also, so 445 must be a structural hybrid, possibly the parent with a double interchange. On data presently available it is not possible to determine the chromosome structure of 63B, although a more intensive investigation of 445 × 63B and of 63B in other combinations should provide evidence of its structure. The fact that antheridia attached to oogonia containing nuclei with multiple associations usually had uniform post-division nuclei may indicate that 63B is a structural homozygote.

The post-division stages of development were of considerable interest in both types of material. In the oogonia, while many periplasm nuclei were roughly half the size of the vegetative nuclei in nearby hyphae, suggesting a haploid condition in the former and a diploid in the latter, other nuclei of varying sizes were observed in the periplasm, indicating a failure of the second division in some cases. Sometimes giant "restitution" nuclei which could have resulted from the failure of both divisions were seen. In maturing oogonia two oospheres rather than the usual one were observed on several occasions. These observations suggest that more than one nucleus, reduced or unreduced, may be included in an oosphere. This could account for the genetical results of Laviola^{4,5}, who obtained more than one genotype among zoospore progenies of some single oospores from crosses in which isolate 445 was involved.

A high frequency of failure of oosphere formation or gametic abortion was observed in the crossed material. Similar high sterility has been reported in other crosses involving isolates 445 and 63B⁵, and in crosses among F₁ progeny of 445×473³. This situation is possibly comparable to the situation in *Pisum sativum*, where 50% of pollen and ovule abortion occurs when an association of four chromosomes is present, and about 75% occurs when two associations of four or one of six are present. In a structural hybrid viable combinations are formed when every pairing segment segregates so that each daughter nucleus contains a balanced genetic complement. Other types of segregation lead to duplications of some segments and deficiencies of others, and are therefore usually inviable. Unequal chromosome segregation leads to the formation of gametes with an extra chromosome and hence to the production of trisomics in the progeny.

In considering the sterility to be expected in *Phytophthora* three other factors must be taken into account. In the crossed material, oogonia and antheridia of both parents may be present and these may differ in chromosome structure. In such a case the percentage of oosphere abortion in a particular sample would depend upon the percentage of oogonia formed by each parent. Second, the oogonium is multinucleate, containing a number of nuclei undergoing meiosis. There is therefore a possibility that if one nucleus leads to inviable combinations another nucleus leading to viable combinations may provide a substitute nucleus for the oosphere. *Phytophthora* resembles higher animals rather than higher plants in that meiosis leads directly to gamete production without a game-

tophyte stage. Thus some deficient types may survive until fertilization when zygotic elimination may or may not occur.

The nuclear behaviour in the material we have examined shows that meiosis occurs in the gametangia, indicating that *P. infestans*, in common with other Oomycetes¹, is diploid in the vegetative state. The occurrence of diploidy and structural hybridity in *P. infestans* should be of interest to those working on the genetics of pathogenicity and disease resistance in potato blight.

We thank Dr C. Laviola for gifts of fungal strains and for providing working facilities.

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Received August 22, 1972.

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Rediscovery of Fraser's Dolphin *Lagenodelphis hosei*

F. C. FRASER¹ described *Lagenodelphis hosei* in 1956 from a skeleton collected by E. Hose² before 1895 on a sea beach in Sarawak. There have been no further records of the species, and its external appearance has remained unknown. We report here the nearly simultaneous, very recent rediscovery of the species in three widely separated areas of the world, and describe its external coloration and form.

On January 27, 1971, at 5° N latitude, 95° 45' W longitude (approximately 800 km west of Cocos Island in the eastern tropical Pacific), the catch of the seiner M/V Larry Roe included approximately twenty-five dolphins of a type unknown to the fishermen. A US National Marine Fisheries Service observer aboard photographed a large male (Fig. 1a and b) and collected a small calf (Fig. 1c and d) of these dolphins. On May 20, 1972, at 5° N latitude, 122° 22' W longitude (about 2,560 km west of the 1971 locality), three more dolphins of the same type, all females, were captured in a net set on yellowfin tuna. The specimens, heavily damaged, have been acquired by the Museum of Comparative Zoology, Harvard University.

On February 17, 1971, at 30° 47' S latitude, 30° 58' E longitude (approximately 80 km south of Durban, South Africa), Best, Gambell, and Ross collected a pregnant female dolphin of an unfamiliar species (Fig. 1e and f). Two days later, at 30° 09' S latitude, 32° 20' E longitude an adult male of the same species (Fig. 1g) was collected. On February 17, 1972, another specimen, an immature female (Fig. 1h and i) was taken in the same area, at 29° 33' S latitude, 32° 12' E longitude.

On March 1, 1971, an adult female dolphin (Fig. 1j and k) of a species unfamiliar to local residents was washed ashore at Coff's Harbour, New South Wales, Australia (30° 10' S latitude, 153° 10' E longitude). D. H. Brown collected the specimen and forwarded it frozen to the University of Sydney.

We have compared the prepared skeletons of the 1971 South African specimens and the eastern Pacific calf with photographs and a partial cast of the type specimen of *L. hosei* and conclude that they belong to that species. The adult specimens (Table 1) agree closely with the type in meristics, measurements, and proportions (the two skulls bracket the type in over half of the proportional measurements), and the

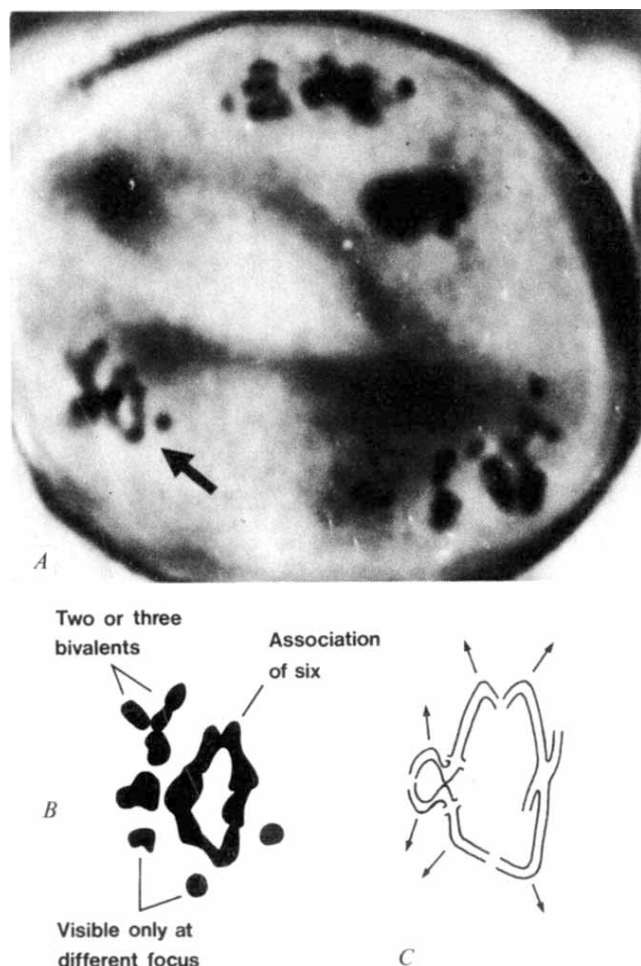


Fig. 1 A, Aceto-orcein squash of 445×63B (× c.13,000). An oogonium with a nucleus (arrowed) showing an association of six and four or five bivalents (two others out of focus). B, Drawing of the arrowed configuration. C, Possible interpretation of the association of six. Arrows indicate centromeres.

diagnostic features of the genus and species are clearly present (Fig. 2), namely, (generic characters) "general structure of skull including tympano-periotic bones as in *Lagenorhynchus* but rostrum having a pair of deep grooves on the palatal surface and fusion of the premaxillae in the middle line dorsally . . . in the manner of *Delphinus* but not of the same extent," and (specific characters) ". . . about 8 feet [2.5 m] long, with broad cranium and basal width of rostrum about 53% of rostrum length. Rostrum flattened, premaxillae not conspicuously raised above level of adjacent maxillae and not varying much in width throughout their rostral length. Post-temporal fossae of moderate size and suboval in shape. Teeth R 44/42 L 43/ca40. Lower jaw rami with a low rounded keel in the neighbourhood of the symphysis. Teeth length 13.6–17.3 mm, their greater diameter 3.9–4.6 mm and lesser 2.4–3.7 mm. Vertebral formula—cervical, 7; thoracic 15, lumbar 21; caudal 37—total number 80 (correct within one or two)."¹

Agreement in meristics is well within the limits of individual variation to be expected on the basis of the range of variation for other, better-known delphinids. The premaxillae of the female specimen are not fused, but incipient fusion is indicated by convergence of the bones, as in young specimens of *Delphinus*. The calf agrees well with the type in meristics, the palate is grooved and the premaxillae converge. The skeletons of the eastern Pacific specimens collected in 1972, the Australian specimen and the third South African specimen have not yet been examined, but we refer them also to *L. hosei* on the basis of their close similarity with the other South African and the earlier eastern Pacific specimens in the distinctive colour pattern and in the external size and shape.

Fraser named his new genus *Lagenodelphis* because the skull of the type possesses features of the genera *Lagenorhynchus* and *Delphinus*. *L. hosei* is in some respects intermediate in external shape (Table 2) as well. The snout is short as in

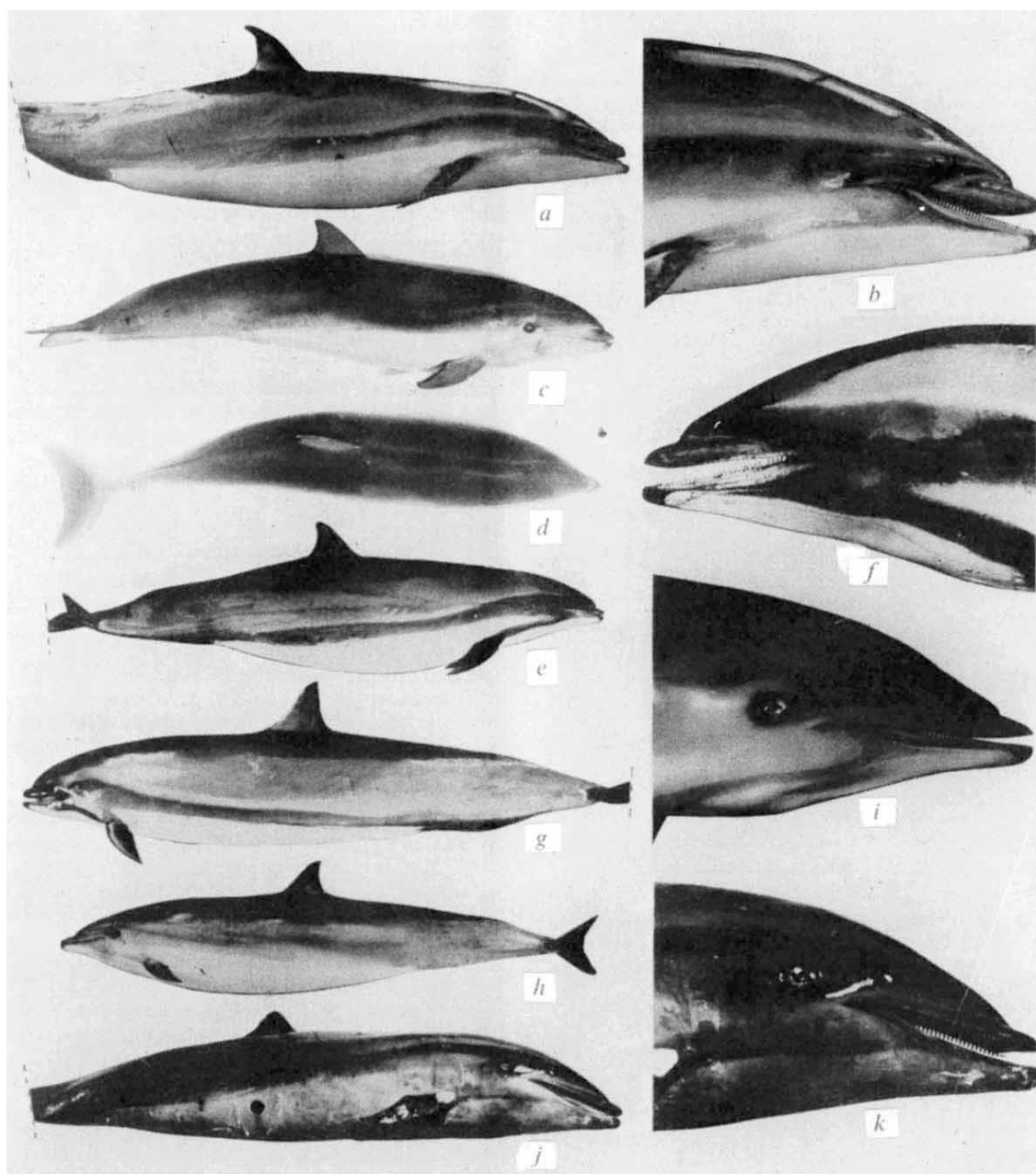


Fig. 1 *a* and *b*, Specimen LR22, male, 226 cm, from eastern Pacific. *c* and *d*, Specimen LR23, male, 110.2 cm, from eastern Pacific. *e* and *f*, Specimen PBB71/3 (SAM 36322), female, 236 cm, from off Natal, South Africa. *g*, Specimen PBB71/4 (SAM 36323), male, 264 cm, from off Natal, South Africa. *h* and *i*, Specimen PBB72/2 (PEM1517/93), female, 225.9 cm, from off Natal, South Africa. *j* and *k*, Specimen from off N.S.W., Australia, female, 226 cm.

Lagenorhynchus but well defined as in *Delphinus*. The overall build is relatively robust as in *Lagenorhynchus*, but the size and form of the appendages are as in *Delphinus*. The dorsal fin is only weakly falcate.

In a letter from Charles Hose to Sir Sidney Harmer dated October 23, 1923¹, the skin colour of the type specimen was described as "greyish or whitish yellow in parts, one might almost say cream colour, but a greyish brown in other parts. . . . The colour is difficult to describe, and it is more than twenty-five years ago." Hose's brother claimed that he had collected this specimen, and noted: "As far as I remember, it was not possible to recognize the colour of the skin, it was so very decomposed"². The coloration of *Lagenodelphis* can therefore be considered as unknown. From colour transparencies of the new specimens, it can now be described as follows.

The most obvious feature is a single dark grey lateral stripe. The dorsum above the lateral stripe is dark greyish blue with a brownish hue, and the dorsal fin and both sides of the flippers and tail flukes are similarly coloured. There was a light patch in the centre of the dorsal fin of the large eastern Pacific specimen (Fig. 1a). The ventrum is white tinged with pink in the living and very recently killed animal. A typical delphinid bridle (terminology of Mitchell³) is present, with eye patch, eye stripe, blowhole stripe, and lip patch. There was a definite light grey-blue beak blaze in all animals except the calf, in which there was a suggestion of one. This blaze was bilaterally symmetrical, leaving a narrow strip of dark pigment in the midline of the beak. The blaze compresses the lip patch to a V-shaped patch at the tip of the snout and a narrow line around the edge of the gape, which connects with a similar V-shaped patch at the tip of the lower jaw.

The pattern may be considered in terms of interacting components, as has been done for other delphinids⁴, as a basic "cape pattern" and a "dorsal field overlay". The ventral margin of the cape (best seen in the calf, Fig. 1c and d) arises at the apex of the melon, passes about 6 cm over the eye, dips ventrad to a low point about halfway between flipper base and dorsal fin, and then sweeps dorsad to an area between

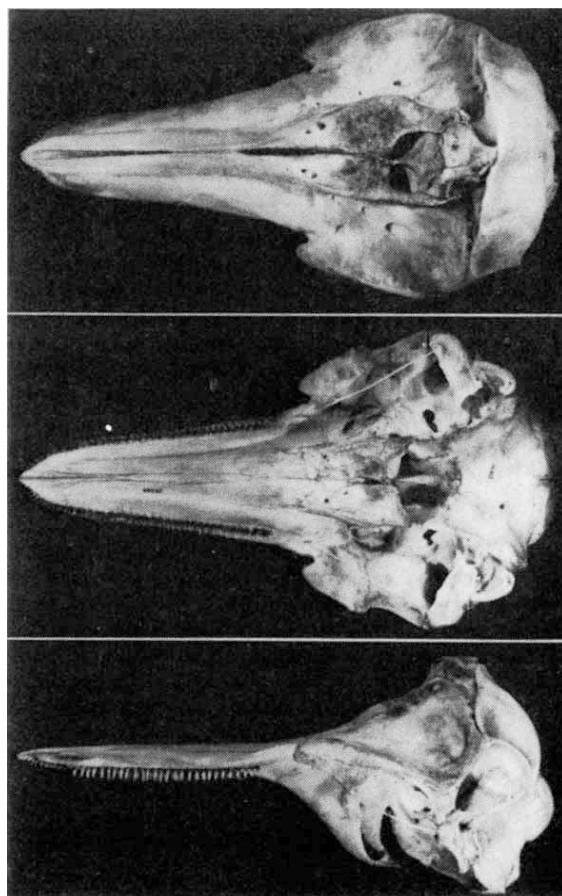


Fig. 2 Dorsal, ventral and lateral views of cranium of PBB71/4 (SAM 36323).

Table 1 Skeletal Measurements and Meristics of Four Specimens of *Lagenodelphis hosei* Fraser, 1956, including the Holotype

Measurement or count	Sarawak specimen (holotype, BMNH1895.5.9.1)* physically mature (from Fraser, 1956)	South African female PBB71/3 (SAM ‡ 36322), physically mature	South African male PBB71/4 (SAM ‡ 36323), physically mature	Eastern Pacific calf LR23 (USNM † 396079)
Condylbasal length	413 mm (100%)	429	440	
Length of rostrum	226 (54.7)	240 (55.9)	241 (54.8)	
Width of rostrum at base	121 (28.3)	119 (27.7)	130 (29.5)	
	(53.5% of rostr. ln.)	(49.6% of rostr. ln.)	(53.9% of rostr. ln.)	
Width of rostrum at midlength	71 (17.2)	71 (16.6)	80 (18.2)	
Width of rostrum 60 mm anterior to antorbital notches	85 (20.5)	86 (20.0)	101 (23.0)	
Least supraorbital width	202 (48.8)	202 (47.1)	218 (49.5)	
Preorbital width	207 (50.1)	207 (48.3)	223 (50.7)	
Postorbital width	230 (55.7)	229 (53.4)	247 (56.1)	
Zygomatic width	225 (54.5)	225 (52.4)	240 (54.5)	
Parietal width	170 (41.2)	161 (37.5)	177 (40.2)	
Maximum width of premaxillae	82 (19.9)	78 (18.2)	83 (18.9)	
Length of upper left tooth row	194 (46.9)	193 (45.0)	213 (48.4)	
Length of lower left tooth row	193 (46.7)	198 (46.2)	207 (47.0)	
Length of left ramus	350 (84.7)	367 (85.5)	375 (85.2)	
Coronoid height of left ramus	70 (16.9)	65 (15.2)	71 (16.1)	
Length of symphysis	36 (8.7)	37 (8.6)	31 (7.0)	
Number of teeth	43 44 ca. 40 42	40 42 39 39	42 42 41 40	42 42 42 44
Total number of vertebrae	80 ± 2	78	78 ± 1	79
Vertebral formula	C7T15L21C37 ± 2	C7T16L21C34	C7T16L + C55 ± 1¶	C7T16L + C56§

* British Museum (Natural History), London.

† US National Museum, Washington, DC.

‡ South African Museum, Cape Town, SA.

§ Counts from radiographs of carcass.

¶ Vertical column disarticulated during preparation; 1-3 small terminal vertebrae missing.

Percentage of condylbasal length in parentheses.

dorsal fin and flukes, where it fragments into a series of diagonal lighter brushings that impart to the posterior half of the animal a chevron pattern when seen from above. The distinctive lateral stripe (eye-to-anus stripe in terminology of Mitchell³) is subsidiary and subparallel to the cape. It also arises at the apex and closely parallels the cape margin for about half the length of the body, diverging ventrad behind the dorsal fin and becoming diffuse above and behind the genital region.

The stripe varies markedly among the specimens in width, clearly defined length, and intensity of pigmentation, in apparent correlation with age. In the calf (Fig. 1c) and the subadult female (Fig. 1h) it is relatively narrow, passing above the eye, and becomes obscure before reaching the genital region. In the larger male from the eastern Pacific (Fig. 1a) (of unknown degree of maturity), the stripe is broader, encompassing the dorsal half of the eye, and is well defined for its entire length to where it interacts with the dorsal overlay system (discussed below) in the genital region. La Grange noted "considerable variation" in the intensity and definition of the stripe among the animals captured with this specimen, some having broader and darker stripes. Observations of animals at sea off the Natal Coast of South Africa indicated that pigmentation of this area was related to size of the animal. In the adult male and female from South Africa (Fig. 1e-g) both larger than the eastern Pacific male, the stripe is still broader, encompassing the eye completely. It appears to be broader than it actually is, however, as its ventral margin can be discerned upon close examination but is obscured by heavy pigmentation of the ventral portion of the dorsal field overlay. In the smaller specimens these two elements are distinct one from the other.

The dorsal field overlay encompasses the flipper stripe and overlaps completely the cape and eye-to-anus stripe. This feature also shows graded development correlated with size, being more lightly pigmented in the smaller specimens. There is a narrow but well-defined light line of demarcation between the anterior end of the flipper stripe and the lip patch. The flipper stripe has a double structure, which is the more clearly defined in the younger animals. The dorsal field in all the specimens has one or two thin posteriorly directed extensions that diverge from the ventral margin and run parallel for several centimetres before disappearing or rejoining the field.

In the genital region of the large eastern Pacific male (Fig. 1a), some interaction can be seen between the eye-to-anus stripe and the structure of the dorsal field overlay. Similar interactions between colour pattern elements may be observed in species of *Lagenorhynchus*³. In the South African adults the interaction is obscured by heavier pigmentation of the dorsal field in this region. Although indications strongly suggest that this and the other trends discussed above are related to development, an alternative explanation of geographical variation cannot be eliminated until known adult specimens from the eastern Pacific and other areas are compared to the South African adults.

Not seen in any of the specimens so far collected, but observed in animals at sea off the Natal coast of South Africa, is a spinal blaze (terminology of Mitchell³) extending from the light-coloured part of the side in a curve up towards the insertion of the dorsal fin.

Similarities in coloration of *Lagenodelphis* to any of the *Lagenorhynchus* species are difficult to demonstrate; there is no tendency towards development of a flank blaze so char-

Table 2 External Measurements of Six Specimens of *Lagenodelphis hosei* Fraser, 1956

Measurement or count	Eastern Pacific specimens		South African specimens			Australian specimen
	LR22, male, unknown degree of maturity	LR23 (USNM* 396079), male calf, 19.3 kg	PBB71/3 (SAM† 36322), adult female, 164 kg	PBB71/4 (SAM† 36323), adult male, 209 kg	PBB72/2 (PEM‡ 1517/93), subadult female, 130 kg§	—, adult female
Total length	226 cm (100%)	110.2	236	264	225.9	226
Tip of upper jaw to centre of eye	—	17.7 (16.1)	33 (14.0)	33 (12.5)	33.1 (14.7)	29.5 (13.1)
Tip of upper jaw to apex of melon	4.5 (2.0)	1.8 (1.6)	4.5 (1.9)	3 (1.1)	4.8 (2.1)	3.5 (1.5)
Length of gape	—	14.3 (13.0)	27.5 (11.7)	27 (10.2)	28.0 (12.4)	24 (10.6)
Tip of upper jaw to external auditory meatus	—	21.1 (19.1)	—	39 (14.8)	38.2 (16.9)	34.5 (15.3)
Centre of eye to angle of gape	—	4.0 (3.6)	5.5 (2.3)	6 (2.3)	6.0 (2.7)	4.4 (1.9)
Centre of eye to centre of blowhole	—	11.0 (10.0)	21 (8.9)	23 (8.7)	19.7 (8.7)	17.6 (7.8)
Tip of upper jaw to blowhole	—	16.5 (15.0)	33.5 (14.2)	28 (10.6)	30.9 (13.7)	28.6 (12.7)
Tip of upper jaw to anterior insertion of flipper	—	24.5 (22.2)	46 (19.5)	43 (16.3)	45.8 (20.3)	42.0 (18.6)
Tip of upper jaw to tip of dorsal fin	—	61.0 (55.4)	133 (56.4)	132 (50.0)	118.4 (52.4)	—
Tip of upper jaw to umbilicus	—	51.5 (46.7)	110 (46.6)	116 (43.9)	106.9 (47.3)	—
Tip of upper jaw to centre of genital aperture	—	71.3 (64.7)	165 (69.9)	170 (64.4)	157.2 (69.6)	—
Tip of upper jaw to centre of anus	—	78.8 (71.5)	175 (74.2)	189 (71.6)	187.7 (83.0)	—
Projection of lower jaw beyond upper	—	0	0.3	1	0.6	0.4
Girth at axilla	—	61.7 (56.0)	110 (46.6)	—	106.9 (47.3)	—
Maximum girth	—	—	132 (55.9)	—	116.5 (51.6)	—
Girth at anus	—	37.9 (34.4)	70 (29.7)	92 (34.8)	70.0 (31.0)	—
Width of blowhole	—	2.0	2.5	4	2.5	2.4
Length of flipper, to anterior insertion	25.1¶ (11.1)	15.2 (13.8)	27 (11.4)	28.8 (10.9)	26.7 (11.8)	25.5¶ (11.3)
Length of flipper, to axilla	18.8¶ (8.3)	10.5 (9.3)	19.5 (8.3)	21.5 (8.1)	20.0 (8.9)	17.3¶ (7.7)
Width of flipper	6.6¶ (2.9)	4.8 (4.4)	8 (3.4)	9.4 (3.6)	8.3 (3.7)	8.1¶ (3.6)
Height of dorsal fin	17.8¶ (7.9)	7.6 (6.9)	17 (7.2)	22 (8.3)	15.9 (7.0)	15.0¶ (6.6)
Span of flukes, tip to tip	49.5¶ (21.9)	22.8 (20.7)	57 (24.1)	59 (22.3)	50.9 (22.5)	47.0¶ (20.8)
Width of fluke, from notch to nearest point on anterior border	—	7.7 (7.0)	13 (5.5)	14.2 (5.4)	13.4 (5.9)	12.6¶ (5.6)

Percentage of total length in parentheses. Measurements taken as specified by Committee on Marine Mammals, American Society of Mammalogists⁶.

* US National Museum, Washington, DC.

† South African Museum, Cape Town, SA.

‡ Port Elizabeth Museum, Port Elizabeth, SA.

§ Measurements converted from inches and eighths to centimetres and tenths.

¶ Measured 10 h after death; some dehydration probable.

|| Measured after exposure to Sun; some dehydration probable.

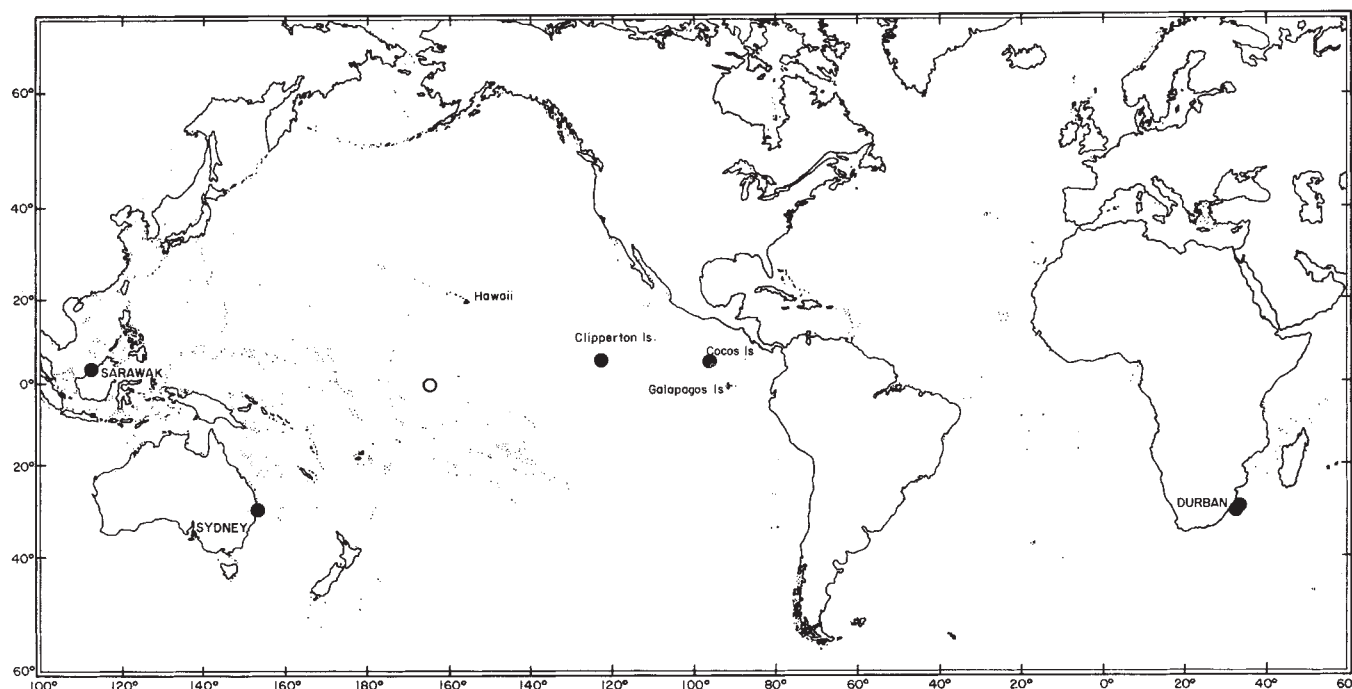


Fig. 3 Recorded occurrences of *Lagenodelphis hosei*. White circle represents sighting record.

acteristic of that genus³, aside from the above-discussed propensity to posterior intersection of the eye-to-anus stripe and dorsal field. The species seems much closer to the *Stenella-Delphinus* group. The overall colour pattern of the adult *Lagenodelphis* is very similar to that of *Stenella coeruleoalba* with the exception of the flipper stripe, which in *S. coeruleoalba* runs to the eye or angle of gape⁵, and the lack of a subtending line below the eye-to-anus stripe in *Lagenodelphis*. A comparison of the young *Lagenodelphis* with *Delphinus* reveals several features in common to both, especially if the longer beak of the latter is taken into consideration. The arrangement of the flipper stripe and eye-to-anus stripe is very similar in both species. The longer mandible of *Delphinus* seems to affect the relative position of these features, so that the flipper stripe extends farther forward in *Delphinus*, and the eye-to-anus stripe is correspondingly farther forward in the head region than in *Lagenodelphis*. *Delphinus* differs markedly, of course, in the development of a large, brightly-coloured thoracic patch (terminology of Mitchell³) which results from the unique partial overlap of cape and dorsal field and which is completely absent in *Lagenodelphis*.

The widely separated localities of collection reported here (Fig. 3) and the close similarity of the specimens to each other

suggest that the species may be continuously distributed in high-seas tropical waters of the Pacific and Indian Oceans. It has also probably been sighted in the Central Pacific. On August 11, 1966, Balcomb observed a school of approximately four hundred dolphins at 165° W longitude on the equator (northeast of the Phoenix Islands). A field sketch and photographs (Fig. 4) clearly show the short, well-defined snout, small subfalcate dorsal fin, small flippers, chunky build, and distinct lateral dark stripe of *L. hosei*.

We thank John La Grange for collecting the eastern Pacific calf and bringing it to our attention, Captains J. Luz of the seiner Larry Roe and J. Adams of the Concho for their assistance, and James G. Mead for preparing the skull of the specimen and providing radiographs of the carcass of the calf. Captain T. Haakestadt and the crew of the whale-catcher C. G. Hovelmeier gave much valuable help in the collection of the South African specimens. We also thank David H. Brown for bringing the Coffs Harbour specimen to our attention. William E. Schevill very kindly allowed us to include the 1972 eastern Pacific record. Edward D. Mitchell provided excellent photographs of the holotype. Kenneth S. Norris, Carl L. Hubbs, and Dale W. Rice read the manuscript.

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Fig. 4 Photo of dolphin sighted by Balcomb northeast of Phoenix Islands.

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The Influence of Prehistoric Cultures upon the Initiation and Spread of Blanket Bog in Upland Wales

THE shallow blanket peats of northern and western parts of the British Isles have received relatively little attention from palynologists. Conway's early work¹ on the Pennines was mainly concerned with deep peats accumulating in high altitude basins and plateaux (for example Ringinglow) which began forming during the Atlantic period. Pollen diagrams of shallower peats on sloping ground from a variety of areas (such as the Pennines², the Lake District³ and Central Wales^{4,5}) suggest their formation began at a rather later date, often about the time of the elm decline.

These shallow peats frequently contain wood remains in their basal layers which give way to an acidic bog peat of *Eriophorum* and *Sphagnum*⁶. Even where wood is absent, there is often evidence from pollen in the underlying soil that there was a former tree cover⁶. The spread of these upland peat bogs and consequent demise of former woodlands has usually been considered due to deteriorating climate, especially a rising precipitation/evaporation ratio. Here I postulate that this vegetational regression was hastened by early human activity of woodland clearance and more especially by stock grazing. This hypothesis is supported by pollen data from a shallow peat near Barmouth in Merioneth, Wales.

Fig. 1 shows the location of the sampling site, close to Llyn Irdryn at 1,000 foot altitude in the Dyffryn Ardudwy coastal region of Merionethshire, Wales (NGR: SH 628222). This area was chosen because of the local concentration of megalithic tombs shown in Fig. 1, and the inset gives the geographical distribution of Neolithic remains in Wales (drawn from the data of Grimes⁷). The megalithic structures

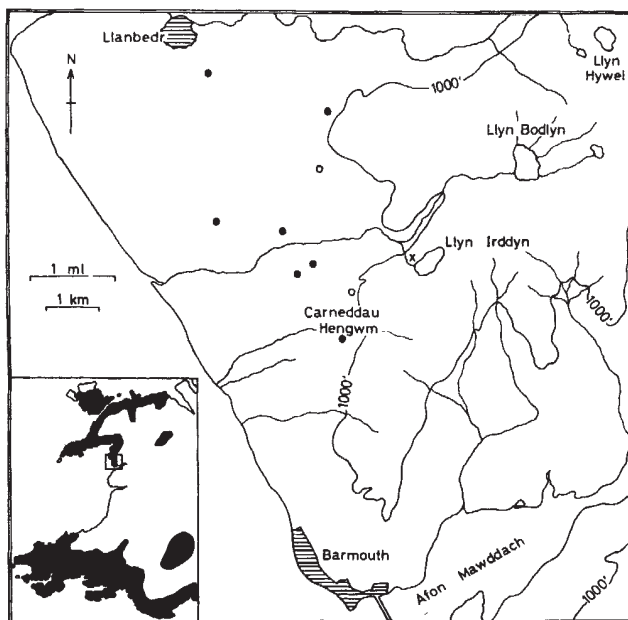


Fig. 1 Map of Barmouth area, Merioneth. ●, Megalithic tomb; ○, stone circle; ×, sampling site. Inset, Wales showing areas with Neolithic remains.

of the Ardudwy region are of the distinctive western long cairn type^{8,9} found in the Lleyn and Pembroke peninsulas of Wales, in Ireland and in Western Scotland.

The site was the closest peat deposit of more than 30 cm depth to the Carneddau Hengwm complex of burial chambers, and it is given that name. Table 1 shows the peat stratigraphic profile. It thus provides an opportunity to study the ecological processes which were operative during the transition from upland wet alder wood to blanket bog. The basal wood peat and the transitional part of the stratigraphy were subjected to pollen analysis using contiguous 0.5 cm samples taken from a peat monolith collected in the field. Results of these analyses are shown in Figs. 2 to 6.

All data (except for fern spores) are expressed as a percentage of the arboreal pollen sum (excluding *Corylus* and *Salix*); 150 tree pollen grains were counted in each sample.

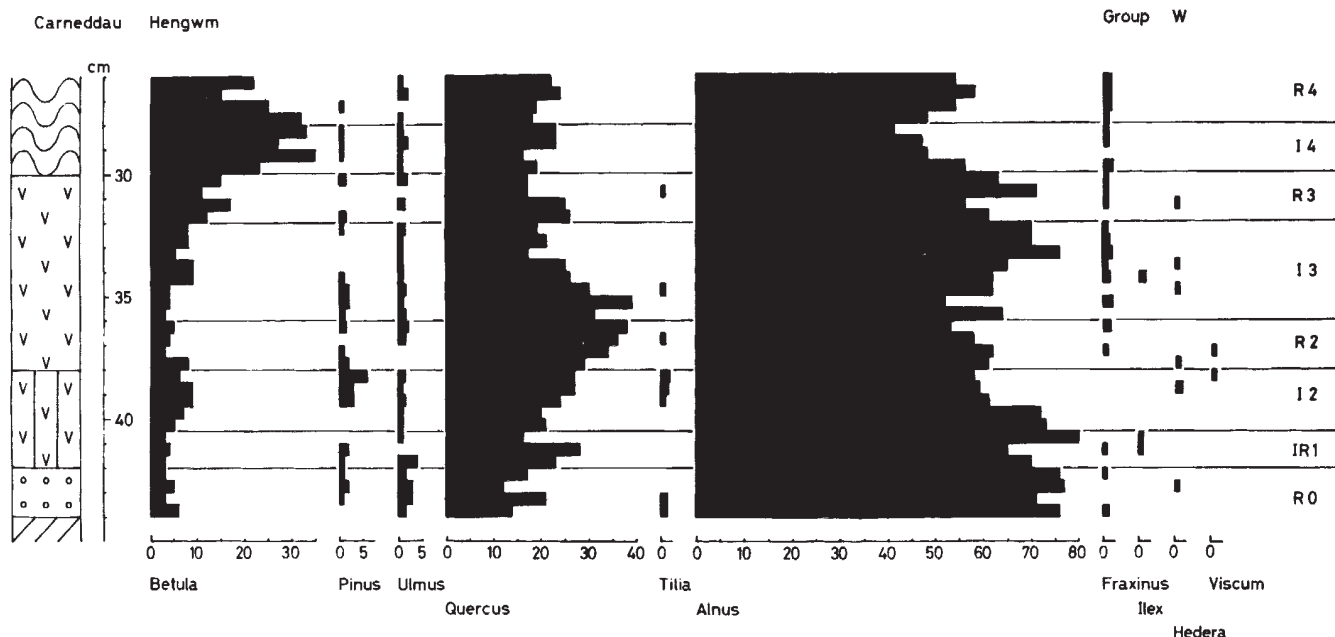


Fig. 2 Stratigraphic profile of the Carneddau Hengwm site and pollen diagram of Group W types, expressed as percentage arboreal pollen. Wavy lines, *Sphagnum* peat; V shading, wood peat; vertical lines, fen peat; circles, downwash gravel.

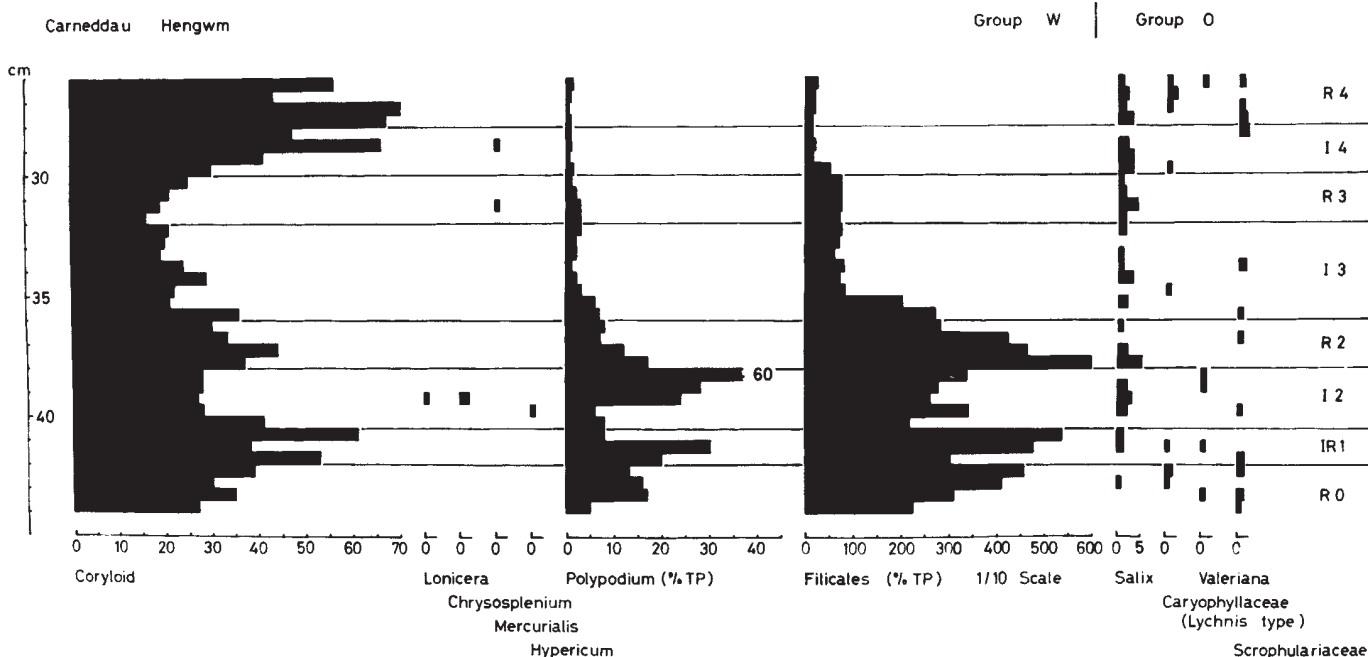


Fig. 3 Pollen diagram of Group W (continued) and Group O types.

Table 1 Stratigraphic Details of the Peat Profile; Macroscopic Remains in Peat

Depth	
0-23 cm	Bog peat of <i>Sphagnum</i> , <i>Eriophorum</i> and <i>Juncus</i>
23-30 cm	<i>Sphagnum</i> bog peat with some seeds indicative of more eutrophic conditions, for example, <i>Juncus bufonius</i> and <i>Lychnis flos-cuculi</i>
30-38 cm	Alder (<i>Alnus</i>) wood peat with <i>Juncus</i> , <i>Carex</i> and <i>Lychnis</i> seeds
38-42 cm	Highly decayed alder wood with fungal (<i>Cenococcum</i>) fruiting bodies
42-44 cm	Gravel and silt with <i>Juncus effusus</i> seeds

The dominance of *Alnus* pollen was not sufficiently great to necessitate its exclusion from the tree pollen sum¹⁰ and expression of local pollen types using a local pollen sum basis¹¹ was not considered helpful here.

In the pollen diagrams the pollen types have been divided

into seven groups on the basis of their ecological requirements (Table 2). Some overlap is inevitable where pollen types such as Gramineae may be represented in more than one group. The diagram has been zoned on its inherent features, especially those which may relate to disturbance of woodland by humans or their animals ('I' phases) and those features associated with recovery and regeneration following such

Table 2 Key to the Habitat Groupings of Species in the Pollen Diagrams

- (W) Woodland, including species of wet woodland floors which might also belong to group O (for example, *Chrysosplenium*).
- (O) Open woodland.
- (B) Poor pasture and blanket bog.
- (H) Aquatic habitats.
- (P) Grassland and habitats managed for pastoral agriculture.
- (F) Arable land.
- (A) Montane habitats.

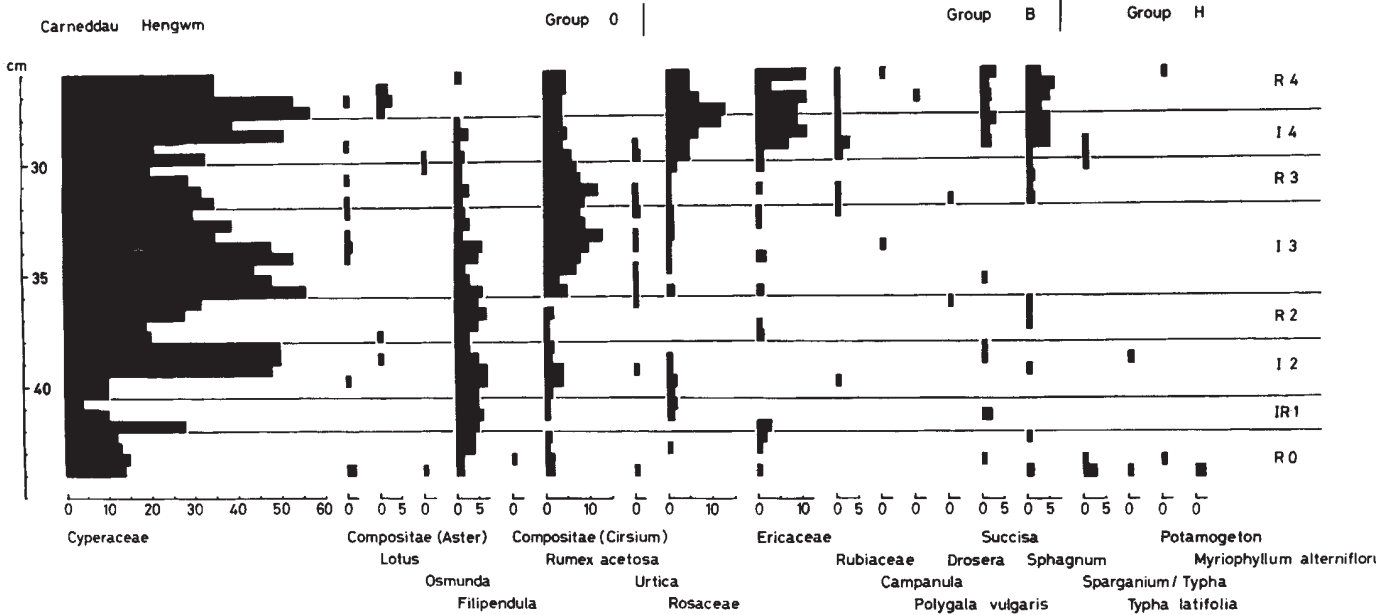


Fig. 4 Pollen diagram of Group O (continued), Group B and Group H types.

Table 3 Description of the Pollen Zones and their Interpretation

Pollen zone	Features	Possible causes
R0	Peat initiation, increasing ferns and <i>Filipendula</i>	Little human activity. Canopy may have been opening as woodland became wetter
IR1	Fall in <i>Alnus</i> ; rise in <i>Quercus</i> , fern spores and <i>Juniperus</i> pollen	Local clearance opening the canopy and allowing a greater proportion of regional pollen into the peat. Regeneration follows
I2	Increase in herbaceous, marsh species. <i>Plantago lanceolata</i> appears in quantity	Local and regional clearance. Pastoral and arable activity on a regional scale; possible local eutrophication
R2	Increase in <i>Alnus</i> , and in species of group B	Canopy closure; reduced local diversity; local and regional regeneration
I3	<i>Filipendula</i> and ferns decrease; <i>Urtica</i> and <i>Rumex acetosa</i> increase, <i>Quercus</i> decreases, <i>Betula</i> and <i>Fraxinus</i> increase, cereal pollen appears	Major regional interference phase with arable cultivation. Local flora shows trend towards low nutrient status with the exception of <i>Urtica</i> which may indicate local phosphate flushing
R3	<i>Rumex acetosa</i> and Cyperaceae fall; bog types increase; <i>Juniperus</i> reaches a peak; seed of <i>Juncus bufonius</i> in stratigraphy	Some regional regeneration. Locally grazing and trampling may have continued
I4	<i>Alnus</i> falls and <i>Betula</i> increases; increases in Gramineae, <i>Plantago</i> , <i>Pteridium</i> and bog types	Considerable local changes, the <i>Alnus</i> woodland degenerating to open bog. Regional changes difficult to discern because of major local changes, but failure of <i>Quercus</i> to rise as <i>Alnus</i> falls suggests concurrent regional woodland clearance
R4	High Cyperaceae, probably <i>Eriophorum</i> (see stratigraphy), some recovery of <i>Quercus</i> and <i>Alnus</i>	Continued bog development locally. Some woodland regeneration on a regional scale

interference ('R' phases), see Table 3. Some of the local and regional changes in vegetation have resulted in changes in the overall diversity as well as the specific composition of the pollen rain. Diversity here is represented by Shannon's diversity index^{12,13} which is given by the formula

$$D = -\sum p_i \ln p_i$$

where p_i is the number of grains of the i th species divided by total grains. The index will be minimal where all grains are of a single species and maximal where each species is represented by only one grain.

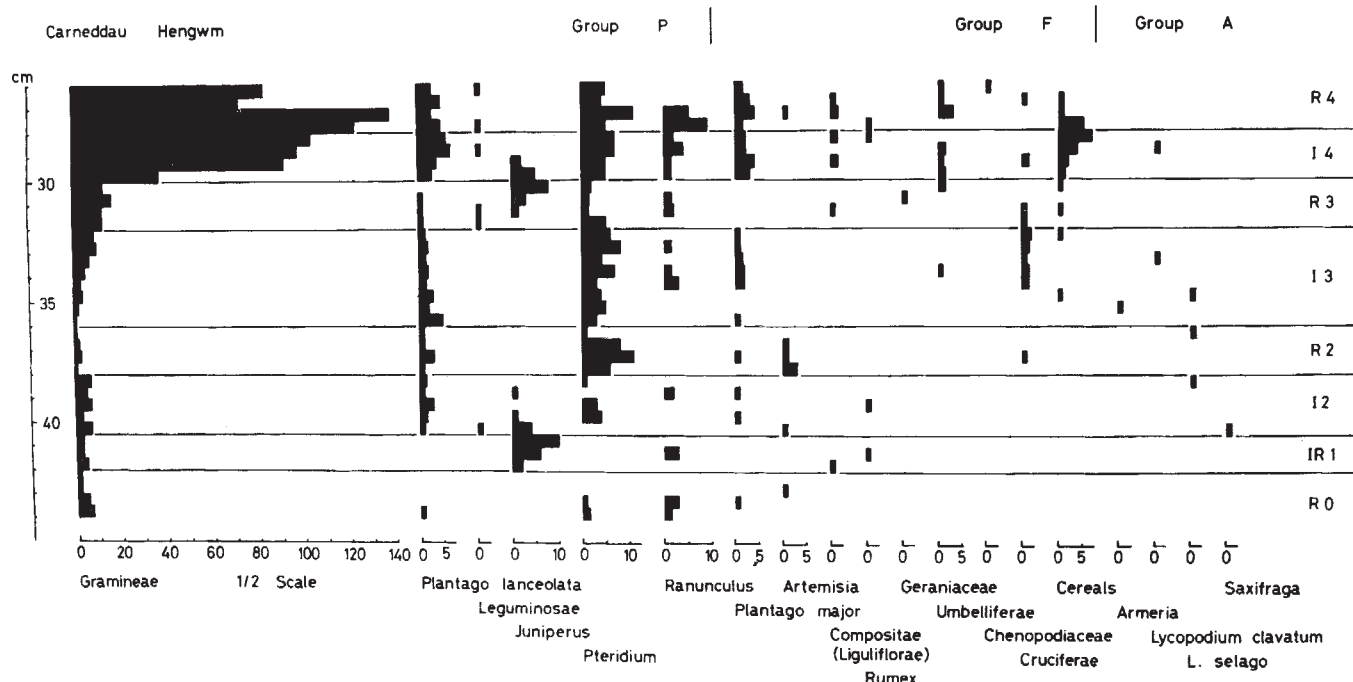
Diversity at each level was computed for both total data and for the local elements on their own. Total diversity (Fig. 6) increases in steps up the profile. There are two possible explanations for this: (i) local vegetation is becoming more diverse, or (ii) the opening of the canopy allows a more diverse pollen representation. Generally there is a tendency for total diversity to increase rapidly during interference phases and to fall, or remain steady, during regeneration phases.

Local diversity is difficult to ascertain because one cannot

determine accurately the proportion of pollen input which can be considered local. The local flora in the basal wood peat and the upper bog peat were different, so the basis for determining local types changes at a depth of 30 cm. Below 30 cm the local diversity curve follows the pattern of total diversity very closely, being greatest during the interference phases and showing a general increasing trend. Above 30 cm the curve becomes erratic, but is on average lower than in phases I3 and R3.

Evidence from the site suggests that, during the period of peat initiation, humans were active in this area, and that their activities had a progressively deleterious effect upon both the local and the regional vegetation. The change in local pollen, both in diversity and specific composition, during interference phases is of particular interest. It demonstrates how human activity, such as shrub or canopy clearance, firing or stock grazing, could have accelerated the degeneration of a damp woodland ecosystem and assisted the spread of blanket bog.

The immediate effects of human activity appear to have been short-term environmental perturbations which have

**Fig. 5** Pollen diagram of Group P, Group F and Group A types.

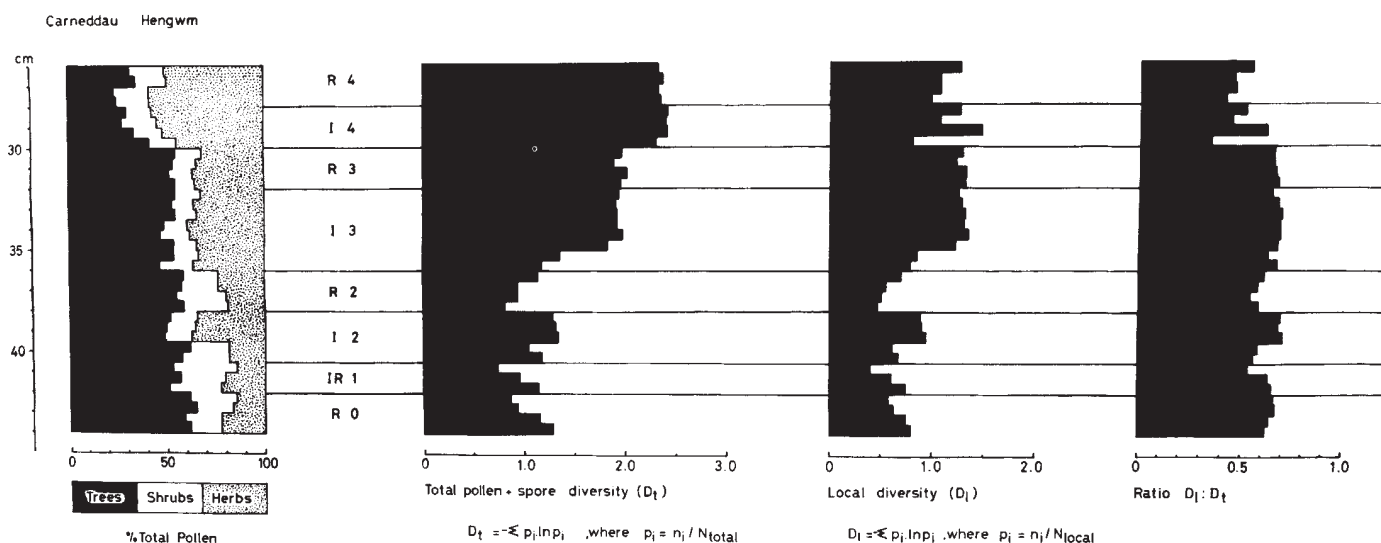


Fig. 6 Summary pollen diagram and pollen and spore diversity diagrams.

increased floral diversity by opening the canopy and eutrophication of the system. Some plants, such as *Juncus bufonius*, may even have been brought in by movements of grazing animals. Continued repetition of such disturbance in a climatic regime where liberated nutrients were subject to leaching inevitably led to retrogressive developments in the ecosystem similar to those described by Iversen at Draved, Denmark¹⁴. The degeneration occurred in a series of steps, being accelerated at each interference phase. The final step led to the collapse of woodland and the initiation of blanket bog.

Thus at Carneddau Hengwm the retrogressive processes described appear to be a consequence not only of a deteriorating climate, which would assist in soil leaching, but also of a series of interferences with upland woods by man and his grazing animals, perhaps commencing in Neolithic times. This must have contributed to the spread of blanket bog in the area.

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Received August 9; revised October 23, 1972.

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Action of Black Widow Spider Venom on an Aminergic Synapse

At the frog neuromuscular synapse Black Widow Spider venom (BWSV) transiently increases the frequency of the

spontaneous miniature end-plate potentials before abolishing the miniature discharge¹, these changes being accompanied by depletion of the synaptic vesicles in the terminals of the motoneurons². It has been suggested that the action of this venom is restricted to cholinergic systems³, a suggestion possibly supported by its inactivity at the squid giant synapse (R. Miledi, personal communication). The fact that studies using fluorescence histochemical techniques indicate that BWSV also depletes transmitter at catecholamine synapses⁴ seems, however, to refute this. In view of this it seemed worth while to examine the effect of BWSV on a non-cholinergic synapse, the insect nerve-muscle synapse where transmission is glutamatergic⁵. The results of these studies were quite unequivocal; BWSV has qualitatively similar effects on glutamate and acetylcholine synapses.

Desiccated whole poison apparatus (Sigma grade II) were ground up in locust saline⁶ and applied to metathoracic extensor tibiae⁷ and retractor unguis⁹ muscle fibres of the locust *Schistocerca gregaria*. The BWSV did not significantly alter the osmolarity and pH of the saline. In most experiments 5 apparatus per 10 ml. were used but, because of their low and variable activity, toxicity could not be standardized. After a variable delay (10–60 min) the miniature discharge of these muscle fibres became very irregular, periods of high frequency (>100 miniature potentials/s) (Fig. 1) being separated by periods of near normal frequency ($\approx$ 3 miniature potentials/s). The cyclic nature of these changes may be due to the complex multiterminal innervation of insect muscle fibres⁹, the venom acting with a variable delay and to a variable extent at different synaptic sites. Similar results were obtained with venom in saline containing sufficient magnesium (50 mmol/l.) to completely block impulse-linked release of transmitter. Miniature potentials could still be recorded from some fibres 12 h post venom treatment although the pattern of the miniature discharge was irregular and the miniature potentials occurred at a very low frequency (1/5 s) (Fig. 2).

A number of nerve-muscle preparations perfused for 4 h with BWSV were fixed with 4% glutaraldehyde and phosphate buffers for 2 h and then post-fixed with 1% OsO₄ for 1 h. Some axon terminals were almost devoid of synaptic vesicles, others contained clumps of vesicles adjacent to the presynaptic membrane⁹, whilst the rest appeared quite normal (Fig. 2). Depleted terminals contained membrane bound structures similar to those seen in lanthanum treated nerve terminals in frog muscle¹⁰. It appears from these data that changes in number and distribution of synaptic vesicles in terminals of insect motoneurons treated with BWSV correlate well with

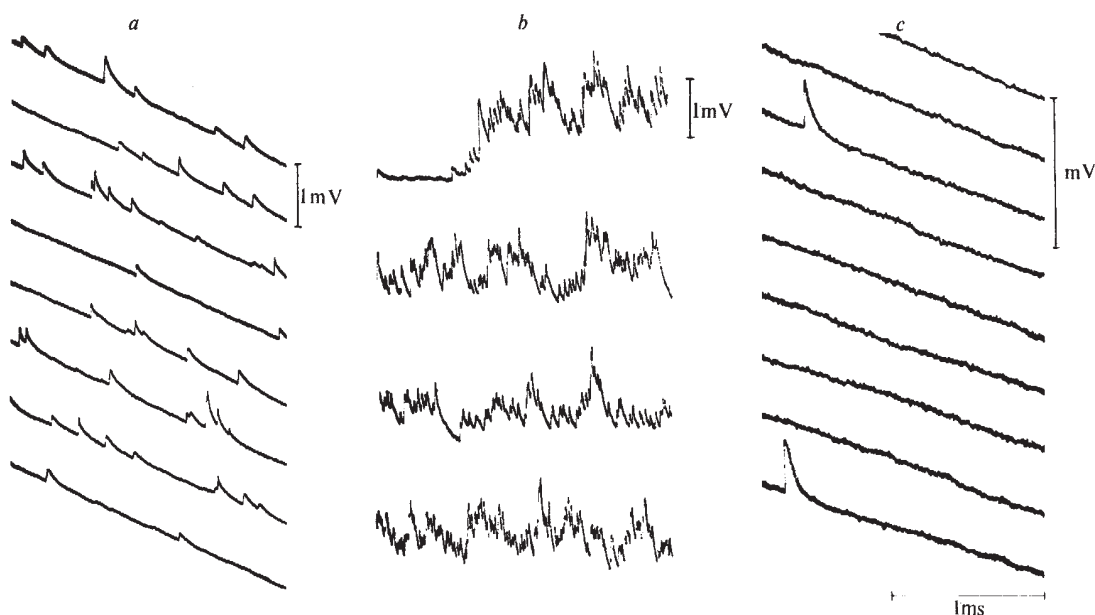


Fig. 1 Miniature discharges recorded from a locust extensor tibiae muscle fibre. *a*, Before treatment with Black Widow Spider venom (BWSV). *b*, During the onset of BWSV action. *c*, 12 h after BWSV treatment.

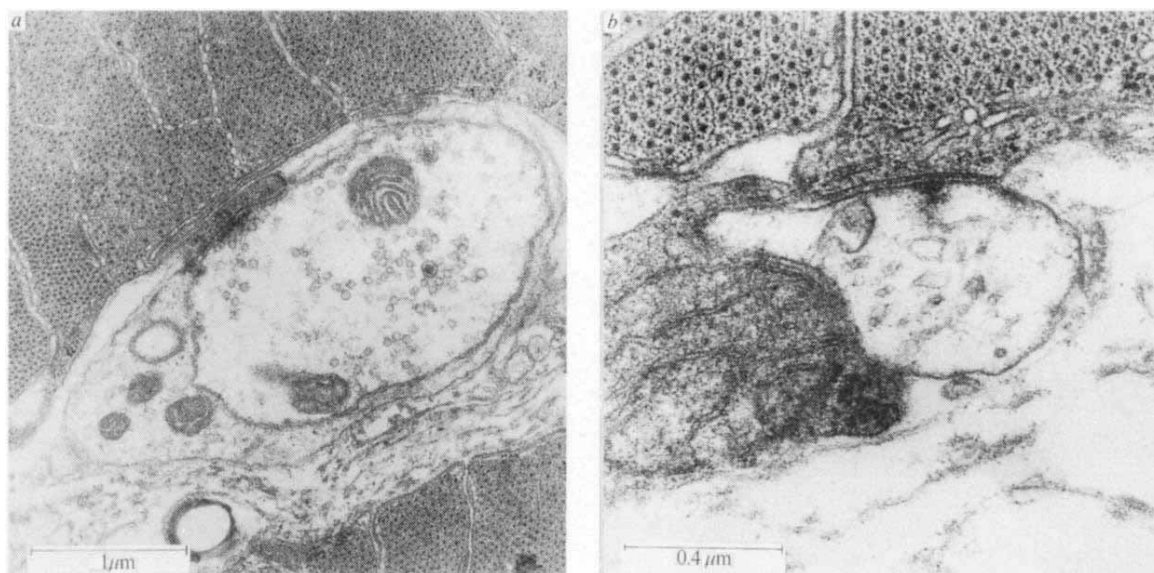


Fig. 2 *a*, Electron micrograph of a normal locust nerve-muscle synapse containing synaptic vesicles. *b*, Electron micrograph of a locust nerve-muscle synapse after treatment with Black Widow Spider venom showing paucity of synaptic vesicles and presence of numerous irregularly-shaped membrane bound structures.

changes in the spontaneous release of transmitter from these terminals.

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Received July 11, 1972.

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Corrigendum

THE authors are indebted to Mr J. Serene for pointing out an error in the derivation of the frequency shift in the article "Properties of a Possible Superfluid State of ^3He " by P. W. Anderson and C. M. Varma (*Nature*, **241**, 187; 1972). As the calculation is stated, the quantity d in equation (9) is unitary and commutes with Δ , and thus gives no splitting of the states of different spin. The fact that we obtain essentially the correct quantitative answers is, however, not a coincidence; a correct derivation which is mathematically similar but based on different principles has been discovered and will be published shortly.